ABSTRACT BOOK

Economic Pathways for Climate-smart and Sustainable Agriculture

ECPCSSA-2026

ECPCSSA-2026
Economic Pathways for Climate-Smart and Sustainable Agriculture

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Abstract Book:
International Conference on
Economic Pathways for Climate-Smart and Sustainable Agriculture (ECPCSSA-2026)

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Preface

We are pleased to present the proceedings of the International Conference on Economic Pathways for Climate-Smart and Sustainable Agriculture (ECPCSSA-2026), a global academic forum dedicated to advancing evidence-based solutions for resilient, inclusive, and sustainable agri-food systems. The conference brings together scholars, policymakers, practitioners, and early-career researchers to critically examine how economic frameworks, institutional reforms, and technological innovation can support agriculture under increasing climate and development pressures.

The response to ECPCSSA-2026 has been highly encouraging, reflecting the growing urgency of climate-smart and sustainable agricultural transformation. Following a rigorous peer-review process conducted by the technical committee and international reviewers, a strong selection of abstracts was accepted for presentation. These contributions represent a wide range of countries, disciplinary perspectives, and methodological approaches, underscoring the global and interdisciplinary nature of contemporary agricultural and development challenges.

The conference themes align closely with pressing global priorities, including climate-smart agriculture, sustainable resource and environmental economics, water–energy–food nexus management, agricultural finance and rural credit, food security and nutrition, and economic resilience under climate risk. Several sessions focus on policy design, institutional effectiveness, and market transformation, highlighting the role of governance, trade, and value chains in shaping sustainable development outcomes.

Technological and analytical innovation features prominently across the program. Contributions explore the economic implications of digital agriculture, artificial intelligence, data-driven decision support, renewable energy integration, and climate analytics, while also addressing equity, access, and ethical considerations. Equally important are discussions on behavioral economics, social inclusion, gender equity, and community-based adaptation, emphasizing that sustainable transitions must be people-centered as well as technologically sound.

Methodologically, the conference shows diverse tools, including econometric modeling, impact evaluation, experimental methods, systems analysis, and mixed-methods research, enabling a more comprehensive understanding of complex agri-food systems.

We extend our sincere appreciation to all authors, reviewers, session chairs, keynote speakers, and partner institutions for their invaluable contributions. We hope that ECPCSSA-2026 fosters meaningful dialogue, stimulates collaboration, informs policy, and contributes to shaping economically viable and climate-resilient agricultural pathways for the future.

ECPCSSA-2026 Organizing Committee

Organizing Committee

The planning and preparation for the International Conference on "Economic Pathways for Climate-Smart and Sustainable Agriculture" – (ECPCSSA-2026) are underway with the guidance of a distinguished team of academic leaders and professionals committed to shaping a globally relevant and intellectually engaging event. We are privileged to have Dr. Anissa Gara from the Département d'Economie-Gestion Agricole et Agroalimentaire (EGAAA), INAT – National Institute of Agronomy of Tunisia, University of Carthage, Tunisia as the Conference Chair, providing strategic direction and academic leadership. The Honorary Planning Committee comprises eminent scholars from Türkiye, China, Mongolia, Uzbekistan, Indonesia, and Pakistan, who are actively contributing their insights and experience to help design a forum that addresses pressing challenges in agriculture, sustainability, and development.

Conference Chair

Anissa Gara**,** Département d'Economie-Gestion Agricole et Agroalimentaire (EGAAA), INAT – National Institute of Agronomy of Tunisia, University of Carthage, **Tunisia**

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Conference Secretaries

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Dr. Muhammad Umar Farrukh, Department of Economics, GC Women University, Sialkot, **Pakistan**

The Organizing Committee, Technical Program Committee, and Conference Secretaries are diligently working to ensure the successful execution of ECPCSSA-2026. Their ongoing efforts in program development, participant coordination, abstract review, and outreach reflect a shared commitment to building a collaborative and inclusive platform for emerging scholars. As preparations continue, we express our deep appreciation to all members involved for their initiative, dedication, and leadership in bringing this important event to life. We look forward to welcoming participants from around the world to this dynamic and forward-thinking virtual forum in January 2026.

Collaborators

the International Conference on "Economic Pathways for Climate-Smart and Sustainable Agriculture" – (ECPCSSA-2026), which will be held virtually from January 26–28, 2026, hosted from Jointly from Tunisia and Pakistan. This unique global event is jointly organized by the Département d'Economie-Gestion Agricole et Agroalimentaire (EGAAA), INAT – National Institute of Agronomy of Tunisia, University of Carthage; Institute of Agricultural and Resource Economics, University of Agriculture, Faisalabad, Pakistan; Department of Agricultural Economics, Selçuk University, Türkiye; and The AgEcon Frontiers (TAEF), Pakistan, in collaboration with a distinguished group of institutional partners.

Our network of collaborators includes a diverse set of national and international organizations, each bringing expertise and thought leadership to the forum. These include:

- Mongolian University of Life Sciences, Ulaanbaatar (Mongolia)
- MNS University of Agriculture, Multan (Pakistan)
- Akdeniz University, Antalya (Türkiye)
- Andijan Institute of Agriculture and Agri-Technologies, Andijan (Uzbekistan)
- Universitas Gadjah Mada, Yogyakarta (Indonesia)
- University of Sargodha (Pakistan)
- The University of Faisalabad (Pakistan)
- Government College Women University, Sialkot (Pakistan)
- Federal University Dutse (Nigeria)
- Agricities (Türkiye)
- Asian Institute of Eco-civilization, Research, and Development, Islamabad (Pakistan)
- Pakistan Economic Frontier, Islamabad (Pakistan)
- The Agricultural Economist – Leading Monthly Magazine
- Journal of Agricultural Policy and Transformation (AgriTaP)

- Department of Food Science and Technology, Jinnah University for Women, Karachi (Pakistan)
- Eurasian Association of Agricultural Economists
- Jinnah University for Women, Karachi (Pakistan)

Together, these institutions support ECPCSSA-2026 as a premier platform for scholars, postgraduate researchers, early-career professionals and academicians working at the intersection of agriculture, environment, climate change, policy innovation, food systems, and sustainability.

Conference Topics

The International Conference on Economic Pathways for Climate-Smart and Sustainable Agriculture (ECPCSSA-2026) was held virtually from January 26–28, 2026, under the central theme *"Economic Pathways for Climate-Smart and Sustainable Agriculture."* The conference was structured around a set of carefully designed sub-themes, each addressing a critical economic, environmental, and institutional dimension of the climate-smart transformation agenda.

Climate-Smart Investments and Resource Use Efficiency focused on innovative economic strategies to optimize land, water, and energy use while maintaining long-term productivity. Discussions emphasized policy instruments, investment incentives, and institutional reforms that support efficient input use, renewable energy adoption, and sustainable agricultural intensification.

Market Dynamics, Trade, and Value Chains under Climate Stress examined how climate shocks disrupt agricultural markets and trade flows. Key issues included price volatility, export competitiveness, value chain integration, and market-based risk management mechanisms aimed at protecting both producers and consumers.

Risk, Insurance, and Finance for Resilient Farming explored financial innovations that address growing climatic and economic risks faced by farmers, particularly smallholders. Sessions highlighted inclusive insurance schemes, microfinance models, and blended finance approaches that enable investment in adaptation and resilience-enhancing technologies.

Recognizing the human dimension of adaptation, **Behavioral Economics and Farmer Adaptation** addressed how farmers perceive risk, respond to incentives, and adopt new practices. Contributions demonstrated how behavioral insights can improve extension services, policy design, and technology uptake at the grassroots level.

Public Policy, Institutions, and Governance emphasized the importance of coherent policy frameworks and effective institutions in scaling climate-smart solutions. Discussions covered cross-sectoral coordination, decentralization, regulatory reform, and public–private partnerships as drivers of systemic change.

Food Security and Livelihoods highlighted inclusive strategies to protect vulnerable populations from climate-induced food insecurity. Special attention was given to gender equity, youth participation, and livelihood diversification as core components of sustainable development.

Digital Innovation and Agricultural Data showcased the transformative role of ICTs, remote sensing, big data, and precision agriculture in improving decision-making, environmental monitoring, and policy formulation.

Finally, **Valuing Ecosystem Services and Natural Capital** addressed the integration of environmental and economic objectives through tools such as Payments for Ecosystem Services,

natural capital accounting, and biodiversity valuation to align conservation with development goals.

Collectively, these sub-themes reflect the conference's commitment to reconciling economic growth with ecological sustainability. ECPCSSA-2026 fostered evidence-based dialogue combining empirical research, modeling, and policy analysis, generating actionable insights for policymakers, development agencies, and the private sector. Ultimately, the conference sought to strengthen global collaboration and contribute meaningfully to the transition toward resilient, inclusive, and climate-smart agri-food systems.

Keynote Speakers

INTERNATIONAL CONFERENCE ON
ECONOMIC PATHWAYS FOR CLIMATE-SMART AND SUSTAINABLE AGRICULTURE
(ECPCSSA-2026)
MEET THE SPEAKERS
Prof. Dr. Mustafa Kan
DEPARTMENT OF AGRICULTURAL ECONOMICS, KIRŞEHIR AHI EVRAN UNIVERSITY, TURKIYE
Prof. Dr. Mian Anjum Murtaza
INSTITUTE OF FOOD SCIENCE & NUTRITION, UNIVERSITY OF SARGODHA, PAKISTAN
Dr. Muhammad Sohail Amjad Makhdum
ASSOCIATE PROFESSOR, DEPARTMENT OF ECONOMICS, GC UNIVERSITY, FAISALABAD, PAKISTAN
Dr. Muhammad Umar Farrukh
ASSISTANT PROFESSOR, DEPARTMENT OF ECONOMICS, GC WOMEN UNIVERSITY, SIALKOT, PAKISTAN
26-28 JANUARY, 2026

Professor Dr. Mustafa Kan is a distinguished Professor of Agricultural Economics at Kırşehir Ahi Evran University, Türkiye, with recognized expertise in agricultural policy, rural development, and extension systems. He holds a PhD in Agricultural Economics from Ankara University, where his doctoral research examined the economic and developmental impacts of geographical indications (GIs), a topic that continues to inform policy debates on territorial development and value-added agriculture.

Professor Kan has built an extensive academic portfolio, authoring over 150 peer-reviewed journal articles and numerous book chapters published nationally and internationally. His scholarly work focuses on sustainable food supply chains, rural livelihoods, agri-food governance, climate change adaptation, and local economic development, with a strong emphasis on translating research into actionable policy insights. He has led and contributed to a wide range of national and international research and development projects, supported by organizations such as FAO, ICARDA, CIMMYT, and various national funding agencies.

In addition to his academic achievements, Professor Kan brings substantial field-based experience, having served as an Agricultural Engineer with the Ministry of Agriculture and Forestry of Türkiye. This practical exposure has strengthened his applied research orientation and engagement with farmers, cooperatives, and extension services. He has held several senior academic leadership positions, including Head of Department, and has contributed extensively to academic governance.

Professor Kan also serves in editorial and advisory capacities for multiple international journals and holds recognized certifications in livelihood analysis and impact assessment. His work reflects a strong commitment to sustainable development, inclusive growth, and evidence-based agricultural policymaking.

Professor Dr. Mian Anjum Murtaza is a highly accomplished scholar in Food Technology and Nutrition, currently serving as Professor and Director at the Institute of Food Science and Nutrition, University of Sargodha, Pakistan. He earned his PhD in Food Technology from the University of Agriculture, Faisalabad, followed by a Postdoctoral Fellowship at the University of Reading, United Kingdom, which significantly strengthened his international research profile.

With over 20 years of teaching and research experience, Professor Murtaza has made outstanding contributions to food science research, particularly in the areas of food security, food safety, food processing, dairy technology, and agricultural waste valorization. He has authored more than 135 research articles in high-impact international journals, with a cumulative impact factor exceeding 350, along with 20 international book chapters. His scholarly work has received over 5,600 citations, and he holds an impressive h-index of 40, reflecting the global relevance of his research.

Professor Murtaza is the recipient of two Gold Medals and one Silver Medal in recognition of his academic excellence and professional contributions. He has supervised 75 MSc students, 13 PhD scholars, and two international postdoctoral fellows, playing a vital role in capacity building and mentorship.

He has successfully completed six major research projects and served as principal organizer for over 30 national and international academic events, including conferences, workshops, and training programs. His work bridges science, innovation, and policy, contributing directly to sustainable food systems and nutrition security at national and global levels.

Dr. Muhammad Sohail Amjad Makhdum is an Associate Professor of Economics at Government College University Faisalabad (GCUF), Pakistan, and a respected scholar in the fields of development economics, agricultural economics, environmental and energy economics, and applied econometrics. He holds a PhD in Agricultural Economics from the University of Kiel, Germany, and completed his MSc (Hons.) and BSc (Hons.) degrees in Agricultural Economics from the University of Agriculture, Faisalabad.

Prior to entering academia, Dr. Makhdum gained valuable professional experience in both the banking sector and public institutions, which enriched his understanding of financial systems, policy implementation, and development challenges. His research is characterized by strong methodological rigor and policy relevance, with a focus on climate change, energy transitions, agricultural productivity, and sustainable development.

Dr. Makhdum has published extensively in high-impact international journals, including *Agricultural Economics, Renewable Energy, Energy, Sustainable Cities and Society, Environmental Science and Pollution Research, Sustainability,* and the *Journal of Environmental Management*. He is an active peer reviewer for numerous reputable journals and has received

multiple research productivity and appreciation awards from GCUF in recognition of his scholarly contributions.

Beyond research, he is deeply engaged in teaching, postgraduate supervision, and academic service, and regularly participates in national and international conferences, workshops, and policy-oriented research initiatives. His work contributes meaningfully to evidence-based policymaking and the advancement of climate-smart and sustainable economic pathways.

Dr. Muhammad Umar Farrukh is an Assistant Professor of Economics at the Government College Women University Sialkot, Pakistan, and holds a PhD in Economics from the University of Agriculture, Faisalabad. He is a multidisciplinary scholar with specialization in health economics and development economics, complemented by strong expertise in agricultural and social policy analysis.

Dr. Farrukh has extensive experience in both primary and secondary data research, with key research interests including farmer behavior under risk and uncertainty, gender and poverty dynamics, food security, agribusiness and supply chain analysis, and social impact assessment. His research addresses critical development challenges at the intersection of health, agriculture, and livelihoods, particularly in low- and middle-income contexts.

Prior to joining GCWUS, he served as a Lecturer and Researcher at the NUML School of Economics, where he contributed actively to teaching, research, and project development. Dr. Farrukh has published his work in reputable international journals and presented research findings at national and international conferences, gaining recognition for his applied and policy-oriented scholarship.

He has also managed and contributed to several multidisciplinary research and development projects, collaborating with economists, social scientists, and development practitioners. His work emphasizes evidence-based solutions for poverty reduction, inclusive growth, and resilient food systems. Dr. Farrukh continues to play an active role in academic mentoring, research dissemination, and policy-relevant engagement.

ABSTRACTS

AgriSmart Pakistan: Leveraging Digital Technology to Transform Agricultural Trade

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Introduction

Agriculture is the backbone of Pakistan's economy, contributing approximately 24 percent to gross domestic product, employing more than 60 percent of the labor force, and accounting for over 40 percent of export earnings. Despite this significant contribution, farmers receive relatively low returns due to inefficiencies in agricultural markets, particularly the dominance of intermediaries and limited access to reliable market information, affordable inputs, and formal finance. The absence of integrated digital platforms restricts farmers' ability to directly engage with buyers, input suppliers, and financial institutions. In this context, technology-driven solutions offer a viable pathway to improve market efficiency, transparency, and farm-level profitability.

Objectives

The study aims to develop and assess a digital agricultural trade platform that educates and supports farmers in digital marketing, enhances direct market access, reduces dependence on intermediaries, improves price transparency through real-time market information, and facilitates access to competitively priced inputs, logistics, and financial services.

Methodology

The study employs a mixed-methods approach using both primary and secondary data. Primary data will be collected through structured meetings and consultations with landowners and key stakeholders. Secondary data will be drawn from existing market reports and digital agriculture initiatives. The research will follow a phased implementation process, including stakeholder engagement and feasibility analysis, platform design and AI model development, pilot testing in Sargodha, expansion to Naushahro Feroze (Sindh), and eventual nationwide scaling. Platform performance and user adoption will be evaluated at each stage.

Results

The expected outcomes include improved farmer–buyer connectivity, reduced transaction costs, enhanced price transparency, and increased farm incomes. The platform is anticipated to strengthen export competitiveness, with potential export growth of up to 50 percent in the initial phase, while significantly improving farmers' livelihoods.

Conclusion and Recommendations

The study concludes that digital agricultural platforms such as AgriSmart Pakistan can substantially enhance market efficiency, farmer incomes, and export performance. It is recommended that government agencies support collaboration between academia, industry, and technology providers to facilitate large-scale adoption and sustainability.

Keywords: Technology, Agriculture, Production, Exports, Returns

International Climate Agreements and Pakistan's National Climate Policies: Implementation Gaps and Coping Strategies

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Introduction

Pakistan is highly vulnerable to climate change, experiencing frequent floods, droughts, heatwaves, and environmental degradation that threaten economic growth and livelihoods. As a signatory to major international climate agreements, including the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, Pakistan has committed to mitigation and adaptation targets through its Nationally Determined Contributions (NDCs). Despite these commitments, the translation of international obligations into effective national action remains limited due to institutional, financial, and technical constraints.

Objectives

This study aims to assess the alignment of Pakistan's national climate policies with international climate agreements, identify key institutional, financial, and technical barriers to implementation, evaluate ongoing mitigation and adaptation initiatives, and propose policy-relevant recommendations to strengthen climate governance and climate-smart investments.

Methodology

A qualitative case study approach was employed to examine Pakistan's compliance with international climate commitments and the effectiveness of national climate policies. Secondary data were collected from national policy documents, global climate assessments, peer-reviewed literature, and reports from international climate finance institutions. Primary data were obtained through semi-structured interviews and focus group discussions with policymakers, environmental experts, and practitioners engaged in climate governance. Data were analyzed thematically across four dimensions: policy alignment, institutional and legislative challenges, financial and technical constraints, and mitigation and adaptation strategies.

Results

The findings indicate that Pakistan has made progress in climate governance through initiatives such as climate-smart agriculture, early adaptation planning, and water resource management, including the Indus River Initiative. However, significant gaps persist between policy formulation and implementation. Weak institutional coordination, overlapping mandates, limited technical capacity, and slow adoption of low-carbon technologies constrain mitigation efforts. Financial barriers remain prominent, as access to global climate finance is hindered by complex procedures and limited project development capacity. Additionally, climate legislation lacks strong enforcement and monitoring mechanisms, while public awareness and stakeholder engagement remain limited.

Conclusion and Recommendations

The study concludes that Pakistan's climate commitments are only partially implemented. Strengthening institutional coordination, improving enforcement mechanisms, enhancing access to climate finance, and increasing stakeholder engagement are essential to bridge implementation gaps and advance climate resilience and sustainable development.

Keywords: UNFCCC, NDC, GCF, GHG, IPCC

Market Volatility because of Climate Change: Implications for Agrifood Value Chains

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Introduction

Climate change has significant consequences for agricultural and food markets at both global and regional levels. These impacts increase market volatility, amplify price fluctuations across value chains, and pose severe risks for developing countries, where producers have limited adaptive capacity and markets function inefficiently. Understanding how climate shocks transmit through prices, trade flows, and supply chain coordination is essential for designing resilient agri-food market systems.

Objectives:

This research aims to (i) analyze the effects of climate shocks on market volatility, trade performance, and the efficiency of agri-food value chains; (ii) assess the suitability of current market-based risk management tools; and (iii) propose policies that enhance the resilience and adaptive capacity of producers, consumers, exporters, and other stakeholders affected by climate-induced disruptions.

Methodology:

A mixed-methods approach was employed, integrating econometric analysis with qualitative value chain assessments. Vector Autoregression (VAR) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models were applied to time-series data on climate indicators, commodity prices, and trade patterns to examine shock transmission and market volatility. Additionally, value chain interviews were conducted with farmers, traders, processors, and exporters to identify structural bottlenecks and adaptive responses. Scenario analysis was used to evaluate the impacts of potential policy interventions, including price stabilization mechanisms, climate-smart logistics, and risk management instruments such as index insurance and forward contracts.

Results:

Findings reveal that climate variability significantly increases short-term price instability and widens the price margin between farmgate and retail levels, especially during heatwaves and floods. Export-oriented value chains such as horticulture and high-value crops lose competitiveness due to disrupted quality standards, transport delays, and rising input costs. Econometric results confirm strong climate–market linkages, with price fluctuations largely driven by climate shocks. Qualitative evidence highlights weak supply chain coordination, limited access to risk management tools, and inadequate infrastructure. Scenario simulations indicate that climate-smart logistics, improved market information systems, and tailored risk financing instruments substantially reduce vulnerability and support uninterrupted trade flows.

Conclusion & Recommendations

Climate-related stresses have substantial and lasting impacts on agri-food markets, reducing value chain performance and undermining the stability of domestic and international trade. Building market resilience requires a combination of structural improvements and policy reforms. Key recommendations include investment in climate-resilient transportation, digital market information platforms, and cold chain systems, as well as the expansion of market-based risk management instruments such as index insurance, hedging mechanisms, and contract farming to protect producers from sudden shocks.

Keywords: Climate Change, Market Volatility, Agri-food Value Chains, Climate Shocks, Trade Performance, Risk Management

Managing Irrigation Water Conflicts under Increasing Water Scarcity: Policy Evidence from Punjab, Pakistan

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Introduction

Water scarcity driven by climate change, population pressure, and inefficient water management has emerged as a critical challenge to agricultural sustainability. Increasing competition over limited irrigation water has intensified conflicts among farmers, threatening agricultural productivity, rural livelihoods, and social stability, particularly in water-stressed regions of Pakistan.

Objectives:

This study aims to identify the key drivers of irrigation water conflicts and to analyze the conflict management strategies adopted by farmers in two major agricultural districts of Punjab, Pakistan—Sargodha and Sahiwal.

Methodology:

Primary data were collected from 300 farming households using a structured questionnaire. Descriptive statistical analysis was employed to examine the socio-economic characteristics of respondents. A logistic regression model was applied to identify the most significant factors influencing farmers' choice of irrigation water conflict management strategies, including cooperative, negotiated, and formal resolution approaches.

Results:

The results indicate that low education levels, small landholdings, low household income, and farming experience significantly influence farmers' responses to irrigation water conflicts. Perceived water scarcity and farm characteristics were strongly associated with the adoption of different conflict management strategies. Farmers facing severe water shortages were more likely to engage in cooperative or negotiated approaches, while institutional access influenced the use of formal conflict resolution mechanisms.

Conclusion & Recommendations

The findings underscore the importance of effective water management, farmer awareness, and institutional support in mitigating irrigation water conflicts. Promoting sustainable irrigation practices, improving water delivery infrastructure, and strengthening local conflict management institutions are essential for enhancing agricultural resilience and ensuring equitable water allocation in water-scarce regions.

Keywords: Water Scarcity, Irrigation Conflicts, Conflict Management, Agricultural Policy, Sustainable Water Use

Climate Smart Agriculture, Food Security, and Sustainable Land and Water Management

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Introduction

Water availability has emerged as one of the most critical constraints to global agricultural production. Climate change has intensified the frequency, duration, and severity of droughts, disrupting rainfall patterns and reducing surface and groundwater resources. In Pakistan, agriculture consumes over 90% of freshwater resources, yet irrigation efficiency remains low, making it increasingly difficult to meet crop water requirements throughout the growing season.

Objectives:

This study aims to examine the implications of water scarcity and climate-induced drought stress on soybean productivity, a crop that is moderately sensitive to water stress, under irrigated agricultural conditions in Pakistan.

Methodology:

The study evaluates crop–water relationships by analyzing irrigation water availability, crop water requirements, and growth responses of soybean under varying water stress conditions. Climate variability, irrigation practices, and water-use efficiency indicators are assessed using secondary climatic data and agronomic performance parameters. Emphasis is placed on identifying critical growth stages vulnerable to moisture stress.

Results:

The findings indicate that reduced water availability during key phenological stages significantly constrains soybean growth and yield. Inefficient irrigation practices exacerbate water stress, leading to suboptimal crop performance. Improved water-use efficiency and timely irrigation scheduling were found to mitigate yield losses under limited water supply conditions.

Conclusion & Recommendations

Water scarcity, compounded by climate variability, poses a serious threat to sustainable soybean production in Pakistan. Adoption of efficient irrigation practices, climate-smart water management strategies, and drought-resilient cropping systems is essential to enhance agricultural productivity and ensure long-term water sustainability.

Keywords: climate change, food security, sustainable management, agriculture, resilience, CSI.

Ameliorating adverse effects of drought on growth and yield of pearl millet (*Pennisetum glaucum* (L.) R. Br) by foliar application of commercial salicylic acid.

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Introduction:

Pearl millet (*Pennisetum glaucum* L.) is an important cereal crop valued for its high nutritional content for both human consumption and livestock feed. However, drought stress severely limits its productivity worldwide, a challenge that is intensifying under changing climatic conditions. Salicylic acid (SA), a plant signaling hormone, plays a critical role in regulating plant growth and enhancing tolerance to abiotic stresses.

Objectives:

This study aimed to evaluate the effectiveness of exogenous salicylic acid application in mitigating drought-induced physiological, biochemical, and yield losses in pearl millet.

Methodology:

A field experiment was conducted at Bahauddin Zakariya University, Multan, using two pearl millet varieties, Kamar Masani and Rujhan. The experiment comprised four treatments: control, control + salicylic acid, drought stress, and drought stress + salicylic acid. Salicylic acid (1 mM) was applied as a foliar spray at the onset of mild wilting symptoms. Growth attributes, yield parameters, chlorophyll content, total soluble protein (TSP), antioxidant enzyme activity, and oxidative stress markers were analyzed.

Results:

Drought stress significantly reduced plant growth, yield, chlorophyll content, and total soluble protein, while markedly increasing hydrogen peroxide (H_2O_2), malondialdehyde (MDA), and superoxide dismutase (SOD) activity in both pearl millet varieties. Foliar application of 1 mM salicylic acid under drought conditions substantially alleviated stress effects by improving growth and yield-related traits, enhancing chlorophyll content, increasing SOD activity and total soluble protein, and reducing H_2O_2 and MDA levels in both cultivars.

Conclusion & Recommendations:

Exogenous application of salicylic acid effectively enhanced drought tolerance and productivity in pearl millet by strengthening antioxidant defense mechanisms and maintaining physiological stability. The use of salicylic acid represents a cost-effective and practical strategy for improving crop resilience and yield in drought-prone regions.

Keywords: *Pennisetum glaucum*; Drought stress; Salicylic acid; Antioxidant enzymes; Growth and yield traits

Advances In Soil Chemical Testing for Soil Resilience: Evaluating the effect of Trichoderma Viride and Bio stimulant Application

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Introduction

Soil resilience, the capacity to restore physical structure, biological functions, and chemical integrity, is vital for sustainable agriculture. Advances in analytical techniques, including high-resolution spectrometry, isotopic tracing, molecular probes, and microbiome sequencing, have improved understanding of organic matter dynamics, nutrient cycling, and microbe–mineral interactions. Nevertheless, global soil resilience is declining due to intensive farming, excessive chemical inputs, and heightened climate variability, threatening long-term agricultural sustainability.

Objectives:

This review aims to (i) examine recent advances in soil chemical and biological assessments relevant to soil resilience, (ii) evaluate the roles of *Trichoderma viride* and modern biostimulants in improving soil chemical and biological properties, and (iii) identify research gaps and integrated strategies for enhancing long-term soil resilience under field conditions.

Methodology:

A narrative review of peer-reviewed literature examined soil chemistry, microbial ecology, biological amendments, and biostimulants. Studies on organic matter transformation, nutrient availability, enzyme activity, microbial biomass, and soil structure were analyzed. Special focus was given to *Trichoderma viride*, biostimulants (e.g., seaweed extracts, amino acids, humic/fulvic substances, microbial consortia), and their interactions across diverse soils and management practices.

Results:

Trichoderma viride enhances soil resilience by solubilizing nutrients via organic acids, suppressing pathogens through antimicrobial compounds, and promoting root growth through hormone-like metabolites. Biostimulants complement these effects by improving plant–soil interactions, enzymatic activity, and nutrient uptake. However, most studies evaluate these inputs separately, with limited integration of chemical and microbiological soil indicators under combined application. Emerging evidence indicates that co-application of T. viride and biostimulants enhances soil structure, moisture retention, cation exchange capacity, organic matter stabilization, micronutrient cycling, and microbe–mineral interactions. Yet, short-term and controlled studies dominate, limiting understanding of long-term, field-scale impacts.

Conclusion & Recommendations

Integrating soil chemical analyses with biological indicators provides a more comprehensive understanding of soil resilience processes. Combined applications of *Trichoderma viride* and biostimulants represent a promising, eco-friendly strategy to restore soil health and reduce reliance on synthetic fertilizers. Future research should prioritize long-term, field-based studies that jointly assess chemical and biological parameters to optimize application protocols and support resilient, sustainable agricultural systems.

Keywords: Soil resilience, Trichoderma viride, Biostimulants, Soil chemistry–microbiome interactions Sustainable soil restoration.

Climate Change and Seaweed Health in Indonesia: Impacts, Implications, and the Role of Research for Mitigation and Adaptation

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Introduction

Seaweeds (marine macroalgae) are integral to Indonesia's coastal ecosystems, providing critical ecological functions, supporting biodiversity, enhancing coastal protection, and sustaining livelihoods through aquaculture and value-added industries. However, accelerating climate change manifested through rising sea temperatures, ocean acidification, increased storm intensity, and altered seasonal patterns poses substantial threats to seaweed health and productivity.

Objectives:

This article aims to synthesize current research on the impacts of climate change on seaweed ecosystems in Indonesia, assess associated ecological and socio-economic implications, and emphasize the role of scientific research in informing mitigation and adaptation strategies.

Methodology:

The study draws on a synthesis of existing literature, complemented by evidence from local case studies, farmer-level surveys, and broader ecological assessments. An interdisciplinary approach is applied to examine physiological responses of seaweeds to climatic stressors alongside ecosystem-level and livelihood impacts.

Results:

Findings indicate that climate-induced stress affects seaweed growth, reproduction, and resilience, with cascading effects on coastal biodiversity and aquaculture productivity. Climate variability also exacerbates risks for small-scale seaweed farmers, threatening income stability and coastal livelihoods. Localized research highlights significant spatial and seasonal variability in impacts, underscoring the importance of context-specific adaptation strategies.

Conclusion & Recommendations

Safeguarding Indonesia's seaweed ecosystems under climate change requires interdisciplinary and locally grounded research that integrates ecological, climatic, and socio-economic dimensions. Strengthening scientific evidence, enhancing adaptive management practices, and supporting farmer-centered innovations are critical to building resilience in seaweed-based ecosystems and livelihoods amid ongoing environmental change.

Keywords: climate change, seaweed, health, mitigation, Indonesia

Impact of Water Scarcity and Climate Variability on Soybean Productivity under Irrigated Agriculture in Pakistan

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Introduction

Water availability has emerged as one of the most critical constraints to global agricultural production. Climate change has intensified the frequency, duration, and severity of droughts, disrupting rainfall patterns and reducing surface and groundwater resources. In Pakistan, agriculture consumes over 90% of freshwater resources, yet irrigation efficiency remains low, making it increasingly difficult to meet crop water requirements throughout the growing season.

Objectives:

This study aims to examine the implications of water scarcity and climate-induced drought stress on soybean productivity, a crop that is moderately sensitive to water stress, under irrigated agricultural conditions in Pakistan.

Methodology:

The study evaluates crop–water relationships by analyzing irrigation water availability, crop water requirements, and growth responses of soybean under varying water stress conditions. Climate variability, irrigation practices, and water-use efficiency indicators are assessed using secondary climatic data and agronomic performance parameters. Emphasis is placed on identifying critical growth stages vulnerable to moisture stress.

Results:

The findings indicate that reduced water availability during key phenological stages significantly constrains soybean growth and yield. Inefficient irrigation practices exacerbate water stress, leading to suboptimal crop performance. Improved water-use efficiency and timely irrigation scheduling were found to mitigate yield losses under limited water supply conditions.

Conclusion & Recommendations

Water scarcity, compounded by climate variability, poses a serious threat to sustainable soybean production in Pakistan. Adoption of efficient irrigation practices, climate-smart water management strategies, and drought-resilient cropping systems is essential to enhance agricultural productivity and ensure long-term water sustainability.

Keywords: Water scarcity, Climate variability, Soybean productivity, Irrigation efficiency, Sustainable agriculture

Development of Anthocyanin Based pH-Sensitive Smart Packaging Film Stickers for Food Spoilage Detection

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Introduction

Food waste poses significant global challenges, leading to economic losses, food insecurity, and public health risks. The FAO estimates that one-third of global food production is wasted annually, largely due to inadequate systems for assessing real-time food quality. Conventional expiry date labels rely on predicted storage conditions and fail to accurately represent actual spoilage, resulting in both accidental consumption of spoiled food and premature disposal of edible products.

Objectives:

This study aims to develop a low-cost, environmentally friendly, anthocyanin-based, pH-sensitive intelligent packaging film using polyvinyl alcohol (PVA) and tamarind seed extract to provide a simple, visual spoilage indicator suitable for real-world food packaging applications.

Methodology:

The proposed intelligent film incorporates natural anthocyanins—pH-sensitive pigments derived from plant sources such as red cabbage, berries, and grapes—into a PVA–tamarind seed extract matrix. Anthocyanins exhibit distinct color changes across acidic, neutral, and alkaline conditions. These colorimetric responses were utilized to create a visual indicator capable of detecting pH shifts caused by microbial growth in perishable foods.

Results:

The developed smart film demonstrated clear, observable color changes corresponding to variations in pH associated with food spoilage. The colorimetric response enabled real-time monitoring of freshness in perishable products such as meat, fish, and dairy. The biodegradable and cost-effective nature of the film enhances its suitability for widespread packaging applications.

Conclusion & Recommendations

Anthocyanin-based smart packaging offers a promising solution for reducing food waste and improving food safety by providing consumers with real-time visual indicators of product freshness. The PVA–tamarind seed extract film developed in this study presents an affordable, eco-friendly, and user-friendly tool for intelligent food packaging systems.

Keywords: Anthocyanin, Smart Packaging, pH-Sensitive Film, Polyvinyl Alcohol (PVA), Tamarind Seed Polysaccharide (TSP), Colorimetric Indicator, Food Spoilage Detection, Biodegradable Film, Natural Dye, Food Freshness

Assessment of Environmental Attitudes and Practices of Female Agricultural Workers in the Context of Climate-Friendly Agriculture

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Introduction

Climate change directly impacts agricultural production processes, creating significant pressures on ecosystem balance, food security, and rural livelihoods. In this context, climate-friendly agricultural practices are crucial for the sustainable use of natural resources and the reduction of environmental impacts. In the agricultural sector, female agricultural workers in particular, despite playing an active role in every stage of production, are often insufficiently visible in policy and decision-making mechanisms. Nevertheless, women's relationship with the environment, their knowledge base, and their tendency to conserve resources are important factors in the widespread adoption of climate-friendly agriculture.

Objectives:

This study aims to contribute to sustainable agricultural policies by examining the environmental attitudes and behaviors of female agricultural workers from a climate-friendly agriculture perspective.

Methodology:

The research was structured in accordance with a quantitative research design. A structured questionnaire form was used as the data collection tool. The questionnaire consists of demographic information, agricultural activity characteristics, and Likert-type statements measuring environmental attitudes. It comprises women who have worked in agriculture in Turkey over the last 10 years. This population was of 'unknown (infinite) size'. The sample size was calculated using a formula commonly used for unknown populations and found to be n≈385. The snowball sampling method was applied to achieve this. The data were collected using face-to-face survey techniques. The data obtained were analyzed using statistical software. In addition to descriptive statistics, the relationships between environmental attitudes and variables such as educational level, income status, and agricultural experience were examined through correlation and comparative analyses. The reliability of the scale was tested using Cronbach's alpha coefficient.

Results:

Research findings indicate that female agricultural workers generally exhibit high levels of environmental attitudes towards climate-friendly farming practices. It has been determined that environmental attitude scores increase significantly with higher levels of education and longer periods of agricultural experience. Conversely, it has been established that environmental practices remain limited among groups with lower income levels.

Conclusion & Recommendations

The findings indicate that female agricultural workers should be considered the target group for climate-friendly agricultural policies. The expansion of training and support programs for women will accelerate the transformation of environmentally friendly attitudes into behavior, thereby contributing to sustainable agricultural production.

Keywords: Climate Change, Female Agricultural Workers, Working Women, Sustainable Agriculture.

Resilient but Unequal: Gendered Impacts of Climate Adaptation and Circular Economy Solutions in Kenya's Arid and Semi-Arid Lands

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Introduction:

Agricultural production in Africa's arid and semi-arid lands (ASALs) faces escalating risks from climate variability, including recurrent droughts, erratic rainfall, land degradation, and rising pest and disease pressures. These shocks threaten not only yields but also food security, nutrition, incomes, and household resilience. Women and resource-poor farmers are disproportionately affected due to structural constraints such as limited access to land, credit, and extension services.

Objectives:

This study examined how gendered socio-economic disparities influence the adoption and impacts of climate-smart agriculture (CSA) and circular economy (CE) technologies in Isiolo and Kitui counties, Kenya. It sought to assess whether these strategies promote inclusive resilience or unintentionally reinforce existing inequalities.

Methodology:

A mixed methods impact evaluation design was employed. Quantitative data were collected from 384 households, complemented by 11 focus group discussions and 27 key informant interviews with government officials, development partners, and community leaders. Twenty years of historical climate data were analysed to contextualize household exposure to climate shocks. Multivariate probit models were used to identify determinants of CSA and CE adoption, including water harvesting, wastewater reuse, composting, feed recycling, and integrated pest management. Propensity score matching (PSM) estimated impacts on food security and household income, while cost–benefit analysis (CBA) assessed economic viability.

Results:

Climate shocks were severe, with 96% of households reporting drought-related impacts and average annual losses of US$1,432 in livestock and US$317 in crops. Adoption of CSA and CE practices increased dietary diversity by 26% and household income by 19%. Water harvesting (3.6:1), wastewater reuse (3.2:1), and composting and residue recycling (2.4:1) showed the highest benefit–cost ratios. However, women-headed households were 86% less likely to adopt key technologies, achieving smaller gains in dietary diversity (8%) and income (12%).

Conclusion & Recommendations:

CSA and CE technologies can substantially strengthen resilience, food security, and incomes in ASALs. However, without addressing gender-based barriers to resources and services, these benefits remain uneven. Gender-responsive finance, secure land rights, and equitable extension systems are critical for inclusive, climate-resilient food systems.

Keywords: impact, Gendered adaptation, Food and nutrition security, Propensity Score Matching, Resilience, Kenya

Analyzing Farmers' Water Use Behavior Through the Lens of Behavioral Economics and Social Psychology

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Introduction:

Understanding agricultural producers' water use behaviour (WUB) is critical for designing effective and sustainable resource management policies, especially under increasing global water scarcity and climate change pressures. Conventional economic models often assume farmers make decisions based solely on utility maximization; however, emerging evidence suggests that psychosocial and cognitive factors also shape water-related behaviours.

Objectives:

This study aims to synthesize empirical evidence from the fields of Behavioural Economics and Social Psychology to identify the cognitive, normative, economic, and social factors influencing farmers' WUB across different global regions. A further objective is to evaluate the combined explanatory power of integrated behavioural theories in predicting pro-environmental intentions.

Methodology:

A systematic academic review approach was applied to analyse peer-reviewed empirical studies examining water use decisions among agricultural producers. The review assessed theoretical frameworks including the Theory of Planned Behaviour (TPB) and the Norm Activation Model (NAM) and examined how cognitive, moral, social, and institutional constructs are incorporated into behavioural models.

Results:

Findings show that farmers' water use decisions cannot be explained solely through economic optimization; instead, they result from interactions between bounded rationality and psychosocial motivations. Integrated models combining TPB and NAM significantly increased the explained variance in pro-environmental behavioural intention compared to individual models. Among the strongest predictors of WUB intention were Awareness of Consequence (AC) and Perceived Behavioural Control (PBC). At the social and institutional level, farmer heterogeneity influenced policy responsiveness, while social networks and institutional trust substantially enhanced participation in collective water management. A major behavioural barrier identified was the Perceived Risk of Loss, driven by the cognitive bias of Loss Aversion, which reduced willingness to adopt new conservation practices.

Conclusion & Recommendations:

The review demonstrates the need for policy approaches that extend beyond traditional economic incentives. Effective water management strategies should incorporate behavioural interventions such as targeted nudges, normative communication, and mechanisms to reduce cognitive biases and strengthen institutional trust. These findings underscore the importance of integrating behavioural insights into the design of sustainable water governance frameworks.

Keywords: Behavioral Economics, Water Conservation Behavior, Agricultural Adaptation, Agricultural Policy.

Intentional Action Gap in the Adoption of Climate Smart Agriculture among Small Scale Farmers in Disaster Prone Areas

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Introduction
Pakistan is among the five countries most vulnerable to climate change, experiencing rising temperatures, erratic rainfall, and frequent extreme weather events that threaten agricultural sustainability. Intensified and unsustainable farming practices adopted to meet growing food demand have further amplified these risks. Climate-Smart Agriculture (CSA) provides an integrated approach to improve productivity, enhance resilience, and reduce emissions. However, CSA adoption in Pakistan remains limited, particularly among small-scale farmers due to socioeconomic and institutional constraints. This study examines the challenges and opportunities for promoting CSA adoption to inform targeted interventions that enhance farmers' adaptive capacity and long-term resilience.

Objectives
The study aims to: (i) assess the socio-economic characteristics influencing farmers' awareness and perceptions of CSA; (ii) identify the gap between farmers' intentions and actual adoption of CSA practices; (iii) analyze the barriers preventing the translation of intentions into action; and (iv) propose strategies to bridge the intention–action gap in CSA adoption.

Methodology
A survey-based research design was employed in disaster-prone areas of District Muzaffargarh, Punjab, a region highly exposed to climate-related shocks. Multistage sampling was used to collect data from 200 small-scale farmers. Four disaster-affected areas receiving in-kind CSA assistance were randomly selected, followed by quota sampling of 50 respondents from each area based on water-smart, nutrient-smart, weather-smart, and knowledge-smart interventions. Proportionate representation of male and female farmers was ensured. Primary data were collected through face-to-face interviews using pre-tested questionnaires, complemented by key informant interviews to capture qualitative insights.

Results
The findings indicate that 56% of respondents were male and 44% female, with heatwaves identified as the most frequent climate extreme experienced in the past decade. Approximately 40% owned between 1.1 and 3 acres of land, while most respondents cultivated small vegetable plots under CSA practices. Partial adoption was observed for water-smart (62.5%) and nutrient-smart (47%) practices. Economic incentives and peer influence emerged as key motivators, whereas high input costs and limited in-kind support were major barriers. Gender and household size significantly influenced the adoption of carbon-smart and nutrient-smart practices, with male farmers showing higher adoption rates.

Conclusion and Recommendations
The study highlights a substantial intention–action gap in CSA adoption among small-scale farmers. While awareness and willingness to adopt CSA are evident, financial constraints, high input costs, and inadequate institutional support hinder full implementation. Addressing these barriers through targeted subsidies, gender-sensitive extension services, and sustained in-kind support is critical. Bridging this gap will enhance climate resilience, improve livelihoods, and promote sustainable agricultural development.

Keywords: Climate-Smart Agriculture, Intention–Action Gap, Adoption, Small-Scale Farmers, CSA Assistance.

Digital Transformation for Sustainable Agriculture: Leveraging Data-Driven Innovation to Empower Farmers

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Introduction

Agriculture is increasingly constrained by climate change, population growth, and shrinking natural resources, requiring a shift from conventional production practices. Digital transformation offers a viable pathway to sustainable and climate-resilient agriculture by integrating data-driven technologies into farming systems. Precision agriculture, smart irrigation, remote sensing, and digital advisory platforms improve input efficiency, risk management, and productivity. In developing regions, particularly South Asia, smallholder farmers face persistent challenges related to climate variability, information gaps, and limited market access. Digital technologies can address these constraints by improving access to real-time information and strengthening farm-level decision-making and adaptive capacity. Harnessing digital innovation is therefore essential for advancing agricultural sustainability and food security.

Objectives

This study aims to examine the role of digital innovation and data analytics in empowering smallholder farmers and promoting sustainable agricultural development. Specifically, it investigates how mobile applications, satellite-based monitoring, artificial intelligence, and data-driven advisory services contribute to improved decision-making, optimized resource use, and enhanced resilience to climate variability.

Methodology

The research adopts a qualitative and exploratory design based on a comprehensive review of recent case studies and secondary data from South Asian agricultural economies. A comparative analysis of digital platforms, e-extension services, and climate-smart advisory systems was conducted to assess their functionality, accessibility, and effectiveness. The study also identifies key barriers to adoption, including limited digital literacy, inadequate rural infrastructure, high technology costs, and constraints in data availability and governance.

Results

The findings indicate that digital tools significantly improve farmers' access to timely and location-specific agricultural information, leading to better crop management, higher yields, improved resource efficiency, and increased farm profitability. Mobile-based advisory services and AI-driven crop and weather monitoring systems enhance the accuracy of farm-level decisions and strengthen farmers' capacity to adapt to climate risks. However, the benefits of digital agriculture remain unevenly distributed. Limited connectivity, low levels of digital awareness, and affordability issues continue to restrict adoption among marginalized and remote farming communities.

Conclusion & Recommendations

Digital transformation in agriculture represents not only a technological advancement but also a socio-economic opportunity to build inclusive, climate-smart farming systems. The study recommends targeted investments in rural digital infrastructure, the expansion of digital literacy and capacity-building programs, and the formulation of policies that promote equitable access to agricultural data and digital services. Strong partnerships among governments, private sector actors, research institutions, and development organizations are essential to bridge the digital divide. By recognizing agricultural data as both an economic and social asset, digital innovation can play a pivotal role in fostering resilient rural livelihoods and advancing long-term food security.

Keywords: Digital agriculture, Data innovation, Climate resilience, Smallholder farmers, Agricultural economics

Digital innovation and agricultural data systems at University of Horticultural Sciences, Bagalkot, Karnataka

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Introduction

Information and Communication Technology (ICT) has become a transformative force in modern education, significantly enhancing administrative efficiency, learning delivery, research productivity, and institutional outreach. In agricultural universities, ICT plays an even more critical role by linking academic knowledge with field-level practices. At the University of Horticultural Sciences (UHS), Bagalkot, a wide range of ICT tools has been systematically integrated into academic administration, research management, and extension services. These technologies have streamlined institutional processes, facilitated digital and remote learning, strengthened research collaboration, and enhanced engagement with farming communities. ICT-driven platforms have also enabled the timely dissemination of research-based agricultural knowledge, thereby supporting sustainable horticultural development. This study examines the scope and effectiveness of ICT applications at UHS, assessing their contributions to education, research, and societal outreach within the agricultural sector.

Objectives

The study aims to examine the application of ICT tools at UHS, Bagalkot, and analyze their role in improving academic administration, research management, and extension activities. It further evaluates the impact of these technologies on students, faculty members, researchers, and farming communities, highlighting their contribution to educational quality, research collaboration, and agricultural development.

Methodology

A qualitative research approach was adopted, employing case studies, surveys, and semi-structured interviews with students, faculty members, researchers, and institutional stakeholders. Institutional records and user feedback were analyzed to assess the effectiveness of ICT tools. Key technologies evaluated include ICAR's Academic Management System (AMS), Project Information Management System (PIMS), UHS-Horti App, CeRA, video conferencing systems, VISAKA, e-Governance services, Agri-Diksha portal, and specialized software tools for postgraduate and doctoral research.

Results

The findings reveal that ICT integration has significantly enhanced operational efficiency and academic performance at UHS. AMS enabled automated academic workflows and supported a paperless campus, while PIMS centralized research data and improved collaboration. The UHS-Horti App strengthened farmer outreach by delivering real-time, research-based advisories. Video conferencing connected multiple campuses, facilitating virtual learning and collaboration. Digital initiatives such as VISAKA promoted cashless transactions, while advanced tools, including drones and research software, enhanced precision horticulture and research quality.

Conclusion & Recommendations

ICT initiatives at UHS have substantially improved academic efficiency, research capacity, and community engagement. Continued investment in digital infrastructure, advanced data analytics, and innovative horticultural applications is essential to sustain progress. Strengthening ICT capabilities will further position UHS as a leader in digital agricultural education and innovation.

Keywords: ICT, education, research, Horti-App, UHS

Leveraging an AI-Driven Decision Support System Prototype for Precision Irrigation: An Extension-Led Pilot Study on Rabi Wheat in Bahawalpur, Pakistan

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Introduction

Climate variability and water scarcity increasingly challenge irrigated agriculture in arid and semi-arid regions of Pakistan, particularly Southern Punjab. Declining groundwater, erratic rainfall, and rising temperatures threaten wheat-based cropping systems. Precision irrigation supported by digital decision-support tools can improve water-use efficiency, yet adoption remains limited due to institutional barriers, weak extension linkages, and low user familiarity. Agricultural extension personnel serve as a vital bridge between digital innovations and farm-level practice. This study presents an extension-led pilot assessment of an AI-driven decision support system (DSS) prototype.

Objectives

The study aimed to: (i) develop a prototype DSS dashboard for predictive irrigation scheduling in Rabi wheat; and (ii) assess its feasibility, ease of understanding, and perceived usefulness among agricultural extension personnel and progressive farmers in Bahawalpur district.

Methodology

An AI-driven decision support system prototype integrated agro-meteorological data with crop growth-stage information and was visualized through an interactive dashboard for demonstration. The system operated as a non-operational mock-up to support extension communication and early evaluation. A pilot study was conducted in Bahawalpur during the Rabi season using purposive sampling. Participants included extension personnel (n=20) and progressive wheat farmers (n=12). The prototype was shared digitally, followed by structured online interviews using Likert-scale questionnaires and descriptive statistical analysis methods and tools.

Results

The pilot assessment indicated high feasibility and comprehension of the DSS prototype among extension personnel. More than two-thirds of respondents reported that the dashboard was visually clear and easy to understand. Mean scores for perceived usefulness and advisory confidence exceeded 4.0 on a five-point Likert scale, highlighting strong potential for training and demonstration activities. Progressive farmers also reported positive perceptions, noting improved understanding of crop water requirements and irrigation timing when the prototype was explained through extension facilitation. Comparative insights revealed slightly higher adoption intent among extension personnel, reflecting their intermediary role in digital advisory dissemination.

Conclusion & Recommendations

The study shows that an AI-driven DSS prototype can serve as an effective extension communication and capacity-building tool for promoting precision irrigation in water-scarce regions. Although non-operational, it improved understanding, perceived usefulness, and advisory confidence. Future research should prioritize operational deployment, field evaluation of irrigation outcomes, and stronger extension training.

Keywords: Precision irrigation; Decision support system; Agricultural extension; Climate-smart agriculture; Pakistan

Digital Innovation and Agricultural Data for Climate-Smart and Resilient Farming Systems

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Introduction

The global agricultural landscape is currently navigating a dual crisis of climate instability and systemic inefficiency. As traditional farming reaches its ecological limits, digital innovation offers a paradigm shift from intuition-based to data-driven management. By integrating real-time data with agricultural practices, we can address the urgent need for climate-smart solutions. However, integrating advanced digital tools into everyday farming practices remains complex and requires deeper insight into how data is transformed into actionable knowledge. This study explores the intersection of digital tools and agricultural data as catalysts for economic and environmental sustainability.

Objectives

This research aims to evaluate the effectiveness of digital platforms in enhancing decision-making for resource-constrained farmers. It specifically examines how localized agricultural data can optimize input usage, reduce climate-related risks, and bridge the information gap that currently hinders smallholder productivity and long-term food security.

Methodology

Using a multi-dimensional analytical framework, this study investigated digital adoption patterns across diverse farming clusters. We utilized a combination of qualitative field interviews and quantitative analysis of data-driven advisory systems. The methodology focused on the deployment of mobile-based IoT sensors and satellite imagery analytics in monitoring crop health. We assessed the correlation between high-frequency data access and household income stability. Statistical modeling was applied to determine the impact of predictive analytics on mitigating harvest losses during extreme weather events, ensuring a robust evaluation of digital efficacy.

Results:

The analysis reveals that digital integration leads to a 25% average increase in water-use efficiency and a measurable reduction in chemical runoff. Farmers utilizing real-time data advisory services experienced a 15-20% boost in consistency in yield consistency compared to those relying on traditional methods. Furthermore, agricultural data significantly lowered the barriers to credit by providing financial institutions with verifiable production histories. However, a significant "data-access gap" remains; while technology is available, its benefits are often concentrated among those with higher digital literacy. The results suggest that while digital innovation is a powerful tool for climate-smart agriculture, its success is heavily dependent on the quality of local data infrastructure. Ultimately, the findings demonstrate that data-driven insights are essential for transforming agriculture from a high-risk venture into a resilient economic pathway.

Conclusion & Recommendations:

Digital innovation is no longer a luxury but a necessity for sustainable food systems. To achieve climate-smart agriculture, we recommend that governments prioritize "digital public goods"—specifically open-access soil and weather data. Policies should focus on lowering the cost of digital tools and providing tailored training for smallholder communities to ensure inclusive growth. Future investments must move beyond simple hardware toward creating integrated data ecosystems. By bridging the digital divide, we can empower farmers to make informed decisions that protect both their livelihoods and the planet's resources.

Keywords: Digital innovation, Agricultural data, Climate-smart agriculture, Precision farming, Smallholder resilience, Data-driven decision making

AI-Enabled Agile Framework for Crop Insurance

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Introduction:

Digital revolution Modern agriculture is undergoing a digital revolution, and volumes of data are being gathered on the IOT sensors, satellites and drones in tremendous volumes that is leading to a data explosion. However, essential data is lost in these silos; when data is distributed, it becomes difficult to report and analyse. That fragmentation is a major obstacle in the quest towards a real data driven agriculture that is needed to address those global challenges. The right implementation and application of such heterogeneous data will therefore be perceived as a key to the next level efficiency and sustainability within the industry.

Objectives:
The study explores how digital innovation can offer the integration of heterogeneous data in agriculture.it will develop and prototype a concept model of how such integration will bring more informed on farm decision making process, operations of the sector, and promote sustainable practices of agricultural activities through the provision of holistic understanding via analytics.

Methodology:
The study was mixed research. The systematic literature review provides the digital tool set (e.g., IOT/cloud platforms) and current problems of data interoperability in a systemic manner. It is based on such insights that a theoretical framework of integrated agricultural data platform is offered. This is followed by the discussion of the practicality and usefulness of the framework through a series of qualitative case studies of a group of pilot farms which used precision farming integrated systems.

Results:

The study outlines that the integration of various sources of farm-based data including Machinery, Soil Sensors, Weather Stations and Market Databases can only be done through the combination of digital innovation (e.g., Cloud Data Lakes, APIs and Middleware). It has been a way forward to solving the problem of Interoperability of these systems. In Case Studies it was established that Farms using integrated systems have realized beneficial utilization (i.e. less water and inputs (10 to18%), better Yield Forecasting Accuracy (up to 25% and better Pest Disease Prediction). Moreover, Farm Data, Supply Chain Coordination and Reporting Observance have been enhanced. Still, Cost of implementing the initial setup, Gaps in Data Standardization and varying degrees of Digital Literacy among the End Users was considered the biggest barriers to the adoption of the Framework and both mentioned factors affected the Adoption Rates.

Conclusion & Recommendations:

The entire potential of the usage of digital innovation will transform divided agricultural data into comprehensive strategic resources to utilize to make farmers and the farm more productive with the help of a unified source of data. Smart agriculture relies on the shared platform of all the information generated in the farming process and we would therefore recommend that there should be one common set of industry wide data standards; encouraging low-cost user-friendly data platforms to build this data and then propose certain training opportunities to enhance exploitation of digital capabilities of farmers. Finally, the possibility of applying artificial intelligence to the implementation of predictive analysis and how block chain can provide a secure and transparent means of data exchange using the Agri food supply chain should also be studied in the future.

Keywords: Digital Agriculture, precise farming, Data Interoperability, Farm Management, AI in Agriculture

AI-Enabled Cattle Identification and Recognition Using Retinal Images

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Introduction:
Accurate cattle identification is critical in the management of cattle, control of diseases, elimination of cattle theft, and food traceability. Traditional means of identification, like ear tagging, branding, and Radio Frequency Identification systems, are usually characterized by such problems as loss of the tag, duplication, animal abuse, and human error. The alternative of retinal biometrics is a safe and non-invasive method based on this fact, retinal vascular patterns are unique and permanent, and their consistency does not change over time. This paper provides an AI-powered cattle identification solution with retinal images, which involves image preprocessing, generative data augmentation with Style Generative Adversarial Network, and classical machine learning algorithms to enhance the accuracy of identification and the consistency of the system.

Objectives:
This study aims to design a digital cattle identification system based on retinal images, improving the variety of data based on synthetic image generation with the help of StyleGAN, and assessing the efficiency of classical machine learning algorithms to identify livestock with high precision.

Methodology:
Green channel, CLAHE-based contrast enhancement, and noise reduction processes are applied to the retinal images to display the vascular patterns. A StyleGAN model has been used to create realistic synthetic retinal images to overcome the lack of data, enhancing the diversity of datasets. Classical image processing methods are used to extract features, and the classification is done using traditional machine learning algorithms, that is, Support Vector Machines and K-Means clustering. The system is deployed in Python, which specializes in handling digital data and automated identification of livestock.

Results:

The experimental outcomes suggest that the suggested StyleGAN-aided identification system can considerably enhance cattle recognition. Image augmentation using synthesis also improves the balance of the dataset and the level of classification and identifies objects with an accuracy of between 90 and 95 percent. The system is superior to the baseline methods that are trained on small real data. Accuracy, precision, recall, specificity, F1-score, and confusion matrix evaluation prove that it is resilient to the image quality and illumination conditions. These results verify that model data augmentation with conventional machine learning methods will be effective with digital livestock identification systems.

Conclusion & Recommendations:

The conclusion of this research is that retaining biometrics with StyleGAN-data augmentation makes a trustworthy, precise, and non-invasive solution to cattle recognition in the digital agriculture system. The framework proposed sustains livestock management and decision-making based on data. It is suggested to do future work to include bigger real-farm datasets, to refine the image acquisition methods, and to incorporate the system into the digital livestock monitoring systems to make the system more scalable and useful to deploy in practice.

Keywords: Cattle Identification, Retinal Biometrics, StyleGAN, Digital Agriculture, Machine Learning

Reimagining Agricultural Innovation: The Role of AI-Driven Ideation Support in Sustaining Human Capital in Pakistan

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Introduction

The agriculture sector in Pakistan is central to employment, food security, and economic growth, yet it faces persistent challenges including low productivity, climate stress, skill gaps, and weak knowledge transfer. In recent years, AI-powered ideation support systems such as decision-support tools, smart advisory platforms, and data-driven innovation systems have emerged as key enablers of cognitive engagement. AI-led ideation strengthens human capital sustainability by enhancing learning, problem-solving, and innovative decision-making, fostering a skilled, adaptive, and resilient agricultural workforce capable of meeting future demands.

Objectives

The main objective of this research work is to investigate how AI-based ideation support is relevant to improving cognitive involvement and human capital sustainability in the agricultural industry of Pakistan, particularly in farmers, extension workers, and agricultural entrepreneurs.

Methodology

The study adopts a qualitative and conceptual research design grounded in a review of literature on AI applications in agriculture, cognitive engagement, and human capital sustainability. Secondary data from policy reports, academic studies, and sector analyses on Pakistan's agriculture are synthesized. Thematic analysis is employed to examine links between AI-based ideation tools, learning processes, workforce capability development, and long-term sustainable human capital.

Results:

The results indicate that AI-based ideation support significantly enhances cognitive engagement by promoting sustained learning, reflective thinking, and informed decision-making among agricultural stakeholders. AI-driven knowledge systems, predictive analytics, and advisory tools enable innovative solutions for crop management, resource optimization, and climate adaptation. Enhanced higher-order thinking strengthens skills, confidence, and motivation, contributing to sustainable human capital. In Pakistan, such systems can reduce reliance on traditional practices, bridge research–practice gaps and attract youth. However, digital literacy gaps, infrastructure constraints, and limited data access may restrict benefits without supportive policies and capacity-building initiatives.

Conclusion & Recommendations:

The study adopts a qualitative and conceptual research design grounded in a review of literature on AI applications in agriculture, cognitive engagement, and human capital sustainability. Secondary data from policy reports, academic studies, and sector analyses on Pakistan's agriculture are synthesized. Thematic analysis is employed to examine links between AI-based ideation tools, learning processes, workforce capability development, and long-term sustainable human capital.

Keywords: AI driven ideation support, cognitive engagement, human capital sustainability, agriculture sector

Transitioning from State Procurement to Private Markets: Adapting Chinese Digital Storage Models for Pakistan's Wheat Sector

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Introduction

Pakistan's wheat sector is undergoing a historic structural adjustment. The Government of Punjab's Wheat Support Program 2025 marks a paradigm shift, transitioning from unsustainable state procurement which generates massive circular debt towards a market-driven model utilizing the Kissan Card and Electronic Warehouse Receipts (EWR). However, this transition faces significant friction; smallholder adoption of EWRs remains low due to trust deficits, weak physical-digital verification, and slow financing mechanisms. To address these inefficiencies, this study proposes a comparative framework adapting mature "Digital Grain Bank" models from China to the Pakistani context.

Objectives

This study aims to: (1) assess operational friction in Pakistan's current EWR ecosystem (analyzing the Naymat Collateral Management Company case); (2) benchmark these findings against China's "Internet+Agriculture" financing models; and (3) develop a localized "Digital Post-Harvest Policy Framework" to enhance smallholder liquidity and food security.

Methodology

The research employs a comparative mixed-methods approach. The Pakistan module involves a stratified random survey in Punjab to analyze "Willingness to Store" versus "Willingness to Sell," alongside an institutional process audit of Naymat warehouses. The China module involves a critical policy review of China's "No. 1 Central Document" and a technology assessment of Sinograin's smart depots. These workstreams will be synthesized through econometric modeling of credit risk to create a comparative analysis of post-harvest financing efficiency in both nations.

Results:

As a pre-project conceptual paper, this study anticipates identifying specific regulatory and technological bottlenecks preventing EWR scalability in Pakistan. We hypothesize that the primary barrier is "trust latency" in financing. The comparative analysis is projected to show that adapting Chinese "Digital Inclusive Finance" technologies specifically IoT-enabled storage monitoring and rapid credit risk algorithms can significantly reduce bank loan processing times from days to minutes. The proposed framework will quantify how digitizing grain as a liquid asset can prevent distress sales, potentially increasing smallholder income retention and reducing post-harvest losses by modernizing the storage infrastructure.

Conclusion & Recommendations:

The study concludes that successful privatization requires a "Smart Public-Private Partnership" where the state provides regulatory assurance while the private sector leverages digital efficiency. We recommend a regulatory roadmap for integrating Chinese-style digital verification into Pakistan's Kissan Card scheme. This policy shift ensures national food security by modernizing storage infrastructure and reducing fiscal debt, offering a scalable model for climate-smart post-harvest management in developing economies.

Keywords: Electronic Warehouse Receipts, Digital Grain Banks, Post-Harvest Finance, China-Pakistan Collaboration, Food Security

Determinants of Growers' Intentions to Adopt Blockchain Technology in Pulses Supply Chains

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Introduction

Global food security and sustainability depend heavily on the performance of the agricultural sector. In Pakistan, agricultural productivity plays a crucial role in economic growth and stability. Pulses are an important crop; however, their supply chains are characterized by production instability, weak market linkages, limited transparency, and declining farmer participation. Blockchain technology offers potential solutions by enhancing traceability, transparency, food safety, and direct stakeholder connectivity within agri-food supply chains.

Objectives

This study investigates the key factors influencing pulse growers' intentions to adopt blockchain technology in Pakistan's pulses supply chains.

Methodology

An extended Unified Theory of Acceptance and Use of Technology (UTAUT) model was employed, incorporating perceived risk as an additional construct and perceived cost as a moderating variable. Data were collected through a pre-tested questionnaire using a hybrid purposive–convenience sampling approach from 204 pulse growers in Bhakkar and Chakwal districts of Punjab, Pakistan. Descriptive analysis was conducted using SPSS, while SmartPLS-based Partial Least Squares Structural Equation Modeling (PLS-SEM) was applied for hypothesis testing and structural model evaluation.

Results:

The findings indicate a high level of receptiveness to blockchain adoption when growers are adequately informed. PLS-SEM results confirmed that all UTAUT constructs significantly influence adoption intention, with effort expectancy emerging as the strongest predictor. Perceived risk exhibited a significant negative effect on adoption intention. Furthermore, perceived cost moderated several relationships by strengthening the negative effect of perceived risk and enhancing the positive influence of facilitating conditions on adoption intention.

Conclusion & Recommendations: (up to 100 words)

The study validates the applicability of the extended UTAUT model in an agricultural supply chain context and provides actionable insights for policymakers, practitioners, and technology developers. Addressing cost sensitivity, reducing perceived risks, strengthening trust, and improving facilitating conditions are critical for promoting blockchain adoption in traditional pulses supply chains. Future research should extend this framework through longitudinal and cross-cultural studies to assess adoption dynamics and real-world supply chain impacts.

Keywords: Blockchain technology, Agricultural supply chains, Pulses growers, Technology adoption intention, UTAUT model

Adaptive Behavior and Socioeconomic Drivers of Animal Health Management Among Women Livestock Keepers in Rural Areas of District Faisalabad

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Introduction:

Pakistan is an agricultural country, with livestock serving as the backbone of the sector, with a 62.68% share in agriculture and 14.36% in GDP. In rural areas of Pakistan women perform a variety of livestock management practices. However, women livestock keepers face many challenges in livestock management, especially taking care of animals and ensuring their health. Poor animal health is responsible for economic losses, but women livestock keepers do not implement appropriate animal health management practices due to a lack of knowledge, resources, and decision-making power. In this backdrop, the present study aims to find out the factors affecting animal health management practices among women livestock keepers.

Objectives:

The study aims to identify the socio-economic, cultural, and institutional factors influencing animal health management practices among women livestock keepers in rural Pakistan. It seeks to explore women's access to knowledge, resources, and decision-making, and how these factors impact care, health, and productivity of their livestock.

Methodology:

A multi-stage sampling procedure was utilized to choose the study area and study participants. At the first stage, one tehsil of district Faisalabad, i.e., Tehsil Faisalabad Sadder, was selected randomly for the study purpose. At the second stage, two union councils and two villages from each union council were chosen randomly for the data collection. At the last stage, 30 respondents (women livestock keepers) from each village were selected through simple random sampling technique. Making a sample of 120 respondents. Data were collected through a semi-structured interview schedule, and the collected information was analysed through the Statistical Package for Social Sciences (SPSS).

Results:

The results revealed that most respondents (63.3%) were illiterate and (88%) of respondents felt they lacked government support. A lot of them (80%) were good at finding and dealing with bugs and diseases that can spread from animals to humans. Many women (75%) knew about animal breeding-related problems. Mostly women recognize animal diseases like lumpy skin (83%), respiratory issues (72%), and foot and mouth disease (84%). Then (95%) of women use religious practices (Dam, taweez) for the treatment of animal diseases. Most of the women (75%) knew that vaccinating animals is important, but only 44.2% of respondents utilize vaccines and medicine for animal health management. Bivariate analysis showed that age (χ^2=21.341, p=0.002), education (χ^2=20.801, p=0.002), income (χ^2=18.689, p=0.005), and livestock-keeping experience (χ^2=19.336, p=0.04) were significantly related to animal health management practices, while government support (χ^2=7.364, p=0.118) was not significant.

Conclusion & Recommendations:

These findings highlight the role of socio-economic factors in animal health management. Overall, they showed good awareness about keeping their animals healthy but face challenges like not having much education, decision-making power, money, or any type of government support. They often use traditional ways to keep animals healthy. To empower them, we should teach them more about animals' health, give them subsidies to care for animals, let them be part of decisions, and make sure they can get help from vets.

Keywords: Women livestock keepers, Socio-economic attributes, knowledge about animal diseases, animal health management practices, traditional practices

Analysis of Factors Affecting Agricultural Productivity in Pakistan

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Introduction

Agriculture remains a cornerstone of Pakistan's economy, employing nearly half of the labor force and contributing significantly to gross domestic product, exports, and rural livelihoods. It plays a vital role in food security, poverty reduction, and overall economic stability. However, despite its importance, agricultural productivity growth has remained sluggish over the past decades. This stagnation is largely attributed to inefficient input use, limited access to modern technologies, inadequate credit facilities, and increasing climate variability. Seasonal rainfall fluctuations, land fragmentation, and low adoption of certified seeds further constrain yield potential. Understanding the key drivers of agricultural productivity is therefore essential for designing effective policies that can enhance farm performance, improve rural incomes, and ensure sustainable agricultural development in Pakistan.

Objectives

This study aims to empirically examine the key determinants of agricultural productivity in Pakistan during the period 1990–2025. Specifically, it focuses on the roles of cultivated areas, agricultural credit, fertilizer and pesticide use, certified seed adoption, labor efficiency, and seasonal rainfall in influencing productivity outcomes.

Methodology

The study will utilize secondary time-series data collected from reliable national and international sources, including FAOSTAT, the Pakistan Bureau of Statistics (PBS), the National Fertilizer Development Centre (NFDC), and the Pakistan Meteorological Department (PMD). Econometric techniques suitable for time-series analysis will be employed to assess both short- and long-run relationships between agricultural productivity and its determinants. Diagnostic and robustness tests will be conducted to ensure the reliability and validity of the estimated results.

Results

It is hypothesized that improved access to agricultural credit, efficient fertilizer and pesticide use, and adoption of certified seeds will have a significant positive impact on agricultural productivity and farm incomes. Balanced land utilization and enhanced labor efficiency are also expected to contribute positively to output growth. Additionally, favorable seasonal rainfall is anticipated to play a crucial role in boosting crop yields, highlighting the importance of climate-sensitive agricultural planning.

Conclusion & Recommendations

The study is expected to generate evidence-based insights to guide agricultural policy and planning in Pakistan. By identifying the most critical productivity drivers, the findings will support policies aimed at optimizing input allocation, strengthening extension services, improving access to credit, and promoting sustainable agricultural growth and rural development.

Keywords: Economy, Inputs, Productivity, Rural Development

Consumer Preferences and Willingness to Pay for Fortified Cereals: A Case Study of Faisalabad

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Introduction

Diet is a fundamental determinant of human health and fitness, as it supplies essential nutrients such as proteins, fats, energy, vitamins, and minerals. A diet deficient in these nutrients leads to malnutrition, which remains a serious public health challenge in Pakistan. Food fortification, defined as the addition of essential vitamins and minerals to commonly consumed foods and considered one of the most effective strategies to address this problem. Although food fortification initiatives such as wheat flour fortification, fortified rice, and mandatory salt iodization are implemented in Pakistan, empirical evidence on consumers' willingness to pay for fortified foods remains limited.

Objectives

The primary objective of this study was to empirically estimate consumers' preferences and willingness to pay for fortified cereals, specifically wheat and rice, which are staple foods in Pakistan.

Methodology

This study is based on primary data collected from 165 respondents selected from district Faisalabad. A structured questionnaire is used to gather information on respondents' socio-economic characteristics, health status, family health conditions, food consumption patterns, and awareness of fortified foods. Respondents are also asked about their willingness to pay for fortified wheat and rice. Binary logistic regression and multiple linear regression models are applied separately for wheat and rice to identify the determinants of willingness to pay.

Results

The results indicated that age, gender, and income significantly influenced consumers' willingness to pay for fortified cereals. The effects of education, family size, family type, and number of members of earning varied between wheat and rice. These findings suggest that socio-economic and demographic factors play an important role in shaping consumer preferences for fortified foods.

Conclusion & Recommendations

The study concludes that increasing public awareness about fortified foods is essential to enhance their acceptance and consumption. Government initiatives should focus on awareness campaigns, promotion of bio fortification, and improvement in the quality and marketing of fortified cereals to effectively combat malnutrition in Pakistan.

Keywords: Consumers Preferences, Willingness to Pay, Fortified, Cereals, Faisalabad.

Farmer Adaptation Under Risk: A Dual-Conceptual Framework for Agricultural Decision-Making using Behavioral and Agricultural Economics

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Introduction:

Despite the availability of climate-smart technologies, research, and policy programs, the adoption of adaptive agricultural practices remains uneven across regions and production systems. Traditional agri-economic models often assume farmers to be fully rational decision-makers who respond optimally to prices, policies, and risk signals. However, persistent gaps between recommended practices and actual farmer behaviour suggest that cognitive constraints, social norms, risk perceptions, and behavioural biases significantly shape adaptation decisions.

Objectives:

This study aims to develop and empirically test an evidence-based behavioural economics framework to explain farmers' adaptation to socioeconomic, climatic, and environmental shocks. Specifically, it investigates how behavioural preferences, heuristics, and social influences interact with economic incentives and institutional environments to affect the adoption of climate-smart agricultural practices.

Methodology:

A mixed-methods approach will be employed, combining qualitative and quantitative analyses using both primary and secondary data. Primary data will be collected through structured surveys administered to small- and medium-scale farmers in selected regions, capturing socio-economic characteristics, crop choices, risk perceptions, and behavioural traits. Validated behavioural measures and choice experiments will be used to assess risk preference, loss aversion, time preference, ambiguity aversion, and trust. Secondary data on climate variability, market access, and policy context will be obtained from government agencies and meteorological services. Analytical techniques will include structural equation modelling, discrete choice models, adoption models, and multilevel regression analysis.

Results (expected):

The study is expected to demonstrate that farmers' adaptation decisions are jointly influenced by behavioural constraints and economic incentives. Loss aversion and ambiguity aversion are anticipated to significantly reduce the likelihood of adopting unfamiliar climate-resilient technologies, even when expected economic returns are positive. The behavioural economics–based model is projected to explain a substantially larger share of variation in adaptation outcomes than conventional rational choice models.

Conclusion & Recommendations:

Integrating behavioural economics into agricultural adaptation research offers a more realistic and predictive framework for understanding farmer decision-making under climate risk. The proposed model has the potential to improve policy design by aligning incentives with behavioural realities, thereby enhancing adoption of climate-smart practices, strengthening farm resilience, and supporting sustainable agricultural development amid increasing economic and climatic uncertainty.

Keywords: Climate Smart Agriculture, Technology Adoption, Agricultural Adaption, Agricultural Economics, Climate Risk.

Behavioral Insights of Food Waste-Food Insecurity Paradox: A Review of Determinants of Household Food Wastage Behavior

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Introduction

Household food waste is a major global challenge with serious implications for livelihoods, environmental sustainability, and food security. A key paradox in modern food systems is the coexistence of widespread food waste and persistent food insecurity. Despite millions lacking regular access to nutritious food, quantities of edible food are discarded at the household level. This contradiction is increasingly linked to routine behavioural practices related to purchasing, storage, preparation, and consumption. Understanding these behaviours is essential for explaining how household food waste perpetuates food insecurity.

Objectives

This review aims to synthesize literature on the behavioural, social, and economic determinants of household food waste and explain how these factors contribute to the food waste–food insecurity paradox, highlighting how household behaviours allow both conditions to coexist.

Methodology

A structured literature review was conducted using peer-reviewed articles, international reports, and policy papers retrieved from Scopus, Web of Science, and Google Scholar, covering publications from 2010 to 2024. A narrative synthesis integrates perspectives from sociology, psychology, behavioural economics, and environmental studies.

Results

The literature shows that household food behaviours are shaped by income, household size, employment conditions, and livelihood stability. Higher-income households often waste food through over-purchasing, while lower-income households may waste food due to inadequate storage and limited preservation knowledge. Psychological factors, including weak meal planning, misreading date labels, and negative attitudes toward leftovers, increase avoidable waste. Cultural norms emphasizing abundance normalize over-preparation even under food insecurity. Institutional factors such as weak waste governance and unclear labelling systems further reinforce wasteful practices.

Conclusion & Recommendations

Reducing household food waste is essential for addressing food insecurity and achieving the Sustainable Development Goals, SDG 2 and SDG 12. Effective interventions must integrate behavioral insights with socioeconomic realities and cultural norms. Context-specific strategies that enhance food literacy, promote responsible consumption, and challenge waste-normalizing norms are critical.

Keywords: Food waste; Food insecurity; Household behavior; Behavioral determinants; Sustainable development

Towards A Zero Waste Future: The Development of Ecofriendly Crockery to Reducing the Plastic Waste

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Introduction

The escalating environmental and public health challenges associated with plastic waste have intensified the global search for sustainable alternatives to single-use plastic products. Conventional plastic crockery is widely used in food service and hospitality sectors; however, its non-biodegradable nature contributes significantly to environmental pollution, landfill accumulation, and marine debris. In addition to environmental concerns, plastic tableware poses potential health risks due to the leaching of toxic chemicals such as bisphenols and phthalates into food, particularly when exposed to heat. These concerns are especially relevant in the context of growing street food consumption and takeaway culture. As awareness of environmental sustainability and food safety increases, there is a pressing need for innovative, eco-friendly solutions that can replace plastic crockery without compromising functionality or consumer convenience.

Objectives

This study aims to examine edible crockery as an eco-friendly and health-conscious alternative to conventional plastic tableware. Specifically, it focuses on evaluating the sustainability, safety, functional performance, and practical utility of edible crockery in food service and hospitality applications.

Methodology

The study adopts a qualitative research approach based on a comprehensive review of existing academic literature, industry reports, and recent technological innovations related to edible crockery. Key aspects analyzed include raw materials used, biodegradability, environmental impact, food safety, durability, and usability under different serving conditions. Comparative insights were drawn between edible crockery and conventional plastic alternatives to assess their relative advantages and limitations.

Results

The findings suggest that edible crockery demonstrates adequate strength, durability, and heat resistance to serve a wide range of food products, including hot and liquid items. Its biodegradable and consumable nature significantly reduces solid waste generation and eliminates post-consumption disposal challenges. Moreover, edible crockery removes health risks associated with chemical migration from plastics, offering a safer option for food consumption. The adoption of edible tableware also promotes sustainable consumption behavior and aligns with circular economic principles.

Conclusion & Recommendations

Edible crockery represents a promising innovation capable of transforming food service practices by simultaneously addressing environmental sustainability and public health concerns. Wider adoption can be encouraged through supportive policies, cost optimization, and consumer awareness initiatives. Future research should focus on improving self-life, affordability, and large-scale production to facilitate mainstream adoption.

Keywords: Edible Crockery; Health-conscious; Plastic waste; Environmental pollution; Biodegradable alternative; Sustainability; Human health

Development and Characteristics of Edible Paper from different Vegetables: A Novel Approach towards Biodegradable and Sustainable Primary Packaging

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Introduction

Plastic packaging is extensively used worldwide due to its low cost, durability, and convenience; however, its non-biodegradable nature contributes significantly to environmental pollution and poses potential health risks through chemical migration into food. Growing concerns over plastic waste accumulation and ecological degradation have intensified the global demand for sustainable and eco-friendly packaging alternatives. Edible packaging derived from natural plant-based materials has emerged as a promising solution, offering both environmental and functional benefits. This project addresses these concerns by developing an edible primary packaging material entirely from renewable vegetable sources, promoting sustainability and food safety simultaneously.

Objectives

The primary objective of this study is to develop edible and biodegradable packaging paper using fibrous components extracted from cabbage (*Brassica oleracea*) and bottle gourd (*Lagenaria siceraria*). These vegetables are inexpensive, widely available, and rich in natural biopolymers such as cellulose, pectin, and hemicellulose suitable for film formation.

Methodology

Fibers were extracted from cabbage and bottle gourd through mechanical and aqueous processing techniques. The extracted fibres were blended and combined with natural gums to enhance film-forming properties and structural integrity. Glycerol was added as a plasticizer to improve flexibility, elasticity, and mechanical strength. The homogenized mixture was cast into thin sheets and dried under controlled conditions to produce edible packaging paper. The developed sheets were evaluated for physical appearance and handling properties.

Results

The developed edible packaging paper demonstrated promising characteristics as a sustainable alternative to plastic packaging. The material exhibited acceptable strength, flexibility, and uniformity suitable for food contact applications. Its barrier properties against moisture and gases indicate potential for extending the shelf life of packaged foods. Moreover, the presence of naturally occurring bioactive compounds in cabbage and bottle gourd, including phenols and glucosinolates, suggests inherent antimicrobial and antioxidant activity. These properties may help inhibit microbial growth and oxidative deterioration of food products. The edible nature of the packaging further reduces post-consumer waste and supports circular food systems.

Conclusion & Recommendations

This study highlights the feasibility of producing eco-friendly, edible, and biodegradable packaging paper from low-cost vegetable materials. Developed packaging offers a sustainable alternative to conventional plastics while providing additional functional benefits. Further research is recommended to optimize mechanical strength, shelf stability, and large-scale production potential.

Keywords: edible paper, biodegradable, antimicrobial, antioxidant, fibre

Quantifying Impact and Systemic Vulnerability: A Mixed-Methods Analysis of Flood Effects on Punjab Aquaculture

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Introduction

Aquaculture is an increasingly important contributor to food security and rural livelihoods in Punjab, Pakistan. However, the sector remains highly vulnerable to climate-induced flooding, which causes extensive physical damage, production disruptions, economic losses, and ecological degradation. Recurrent floods have exposed structural weaknesses in pond design, siting, and management practices, while climate variability is intensifying both flood frequency and severity. Despite these risks, the absence of integrated and quantitative assessments has constrained the formulation of evidence-based resilience strategies tailored to flood-prone aquaculture systems.

Objectives

This study aims to quantify flood-related physical and economic losses in aquaculture systems, assess ecological impacts on wild fisheries and spawning habitats, and identify socio-institutional barriers that constrain the adoption of effective risk management and climate adaptation measures.

Methodology

A triangulated mixed-methods approach was applied using data from 2012 to 2024. Geospatial analysis integrated satellite-derived flood extent information with mapped aquaculture pond locations to assess exposure and damage intensity. Structured surveys were conducted with more than 120 fish farmers across Muzaffargarh, Khanewal, and Multan to estimate economic losses and adaptive capacity. Ichthyoplankton surveys and key informant interviews were employed to evaluate ecological impacts on wild fish populations and aquatic habitats.

Results

The analysis reveals pronounced systemic vulnerability within Punjab's aquaculture sector. Farms located in active flood corridors experienced stock losses exceeding sixty percent. Province-wide assessment shows that major flood events, particularly in 2022, damaged nearly one quarter of aquaculture farms in South Punjab, affecting approximately forty to forty-five thousand acres and generating substantial farm-level economic losses. Flood-induced sedimentation and altered hydrological regimes have degraded spawning habitats, threatening wild fisheries. Socio-institutional constraints, including weak early-warning systems, limited insurance access, and poor adoption of climate-resilient pond designs, further undermine adaptive capacity.

Conclusion & Recommendations

Flooding poses a severe and multidimensional threat to aquaculture sustainability in Punjab. Building long-term resilience requires integrated investments in climate-resilient infrastructure, ecosystem-based adaptation to protect fisheries, and strengthened early-warning, insurance, and financial risk-transfer mechanisms to safeguard livelihoods and food security under escalating climate stress globally nationwide.

Keywords: Aquaculture, floods, climate resilience, food security, economic losses, Punjab

Effect of Lead (Pb) and Different Soil Amendments on Biomass Distribution and Morphophysiological Growth Response of *Populus deltoides*

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Introduction
Environmental pollution, particularly contamination by heavy metals, poses a serious global challenge. Lead (Pb) is a persistent heavy metal that readily accumulates in soil and sediments because of industrial activities, adversely affecting plant growth and soil health. Soil amendments such as compost and wood ash have the potential to improve soil fertility and mitigate heavy metal stress when applied in appropriate proportions.

Objectives
This study aimed to evaluate the interactive effects of different soil amendments and lead (Pb) stress on growth performance, biomass distribution, physiological responses, biochemical traits, and nutrient uptake of *Populus deltoides* seedlings.

Methodology
The experiment was conducted at the Research Area of the Department of Forestry and Range Management, University of Agriculture, Faisalabad. Six-month-old *P. deltoides* seedlings were grown under five soil amendment treatments, including combinations of natural soil, compost, wood ash, and lead nitrate [$Pb(NO_3)_2$], arranged in a completely randomized design with eight replications. Morphological, physiological, biochemical, and nutrient parameters were assessed, with physiological measurements recorded using an Infrared Gas Analyzer (IRGA).

Results
Significant differences were observed among treatments. The highest biomass production, improved morphological traits, enhanced physiological performance, optimal nutrient concentrations, and superior biochemical responses were recorded under T3 treatment, which consisted of natural soil (25%), compost (50%), wood ash (25%), and $Pb(NO_3)_2$. In contrast, the control treatment (T0) showed the lowest values for all measured parameters. The T2 treatment, containing a lower proportion of compost (25%), resulted in increased Pb accumulation in roots, stems, and leaves, indicating higher metal bioavailability. Excessive wood ash levels were found to have adverse effects on seedling performance.

Conclusion & Recommendations
The findings demonstrate that compost plays a critical role in mitigating Pb stress and enhancing early growth of *P. deltoides* seedlings, whereas high concentrations of wood ash may be detrimental. An optimal combination of organic and inorganic soil amendments can substantially improve nursery-level growth and stress tolerance of *P. deltoides* under lead-contaminated conditions.

Keywords: Heavy Metals; Agroforestry; Phytoremediation; Lead (Pb)

Nano-Enabled Fertilizers for Sustainable Crop Productivity and Farmer Livelihoods

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Introduction

The increasing global demand for food has intensified the use of conventional nitrogen (N), phosphorus (P), and potassium (K) fertilizers to enhance agricultural productivity. However, their low nutrient-use efficiency and widespread overapplication have raised concerns regarding resource depletion, environmental pollution, and escalating production costs, particularly in low- and middle-income countries. Nutrient losses from conventional fertilizers contribute to soil and water contamination, while recent volatility in global fertilizer prices has further constrained farmers' livelihoods.

Objectives

This study aims to evaluate the potential of nano-fertilizers and slow- or controlled-release nano-formulations as sustainable alternatives to conventional fertilizers for improving nutrient-use efficiency, crop productivity, and environmental sustainability under calcareous soil conditions.

Methodology

Nano-fertilizers based on zinc (Zn), manganese (Mn), and molybdenum (Mo) nanoparticles will be synthesized and physicochemically characterized. Their agronomic performance will be conceptually assessed through their effects on crop growth, nutrient uptake, rhizosphere nutrient dynamics, soil fertility, and microbial activity, with particular emphasis on controlled nutrient release and reduced leaching losses.

Results

Nano-fertilizers and slow-release nano-formulations are expected to enhance nutrient delivery and plant uptake efficiency due to their high surface area and controlled-release properties. Improved nutrient-use efficiency is anticipated to result in higher crop yields, reduced fertilizer losses, lower environmental degradation, and decreased input requirements. These benefits may translate into improved soil health, enhanced microbial activity, and increased economic returns for farmers, especially smallholders.

Conclusion & Recommendations

The adoption of nano-fertilizers and slow-release nano-formulations offers a promising pathway toward sustainable intensification of agriculture. By improving nutrient-use efficiency, minimizing environmental losses, and reducing dependency on high fertilizer inputs, these technologies can support long-term soil fertility, resilient farming systems, and global food security.

Keywords: Nano-fertilizers, Controlled-release fertilizers, Nutrient use efficiency (NUE), Sustainable agriculture, Crop productivity, Soil fertility, Smallholder farmer livelihoods

Marine-Derived Urease-Producing *Bacillus subtilis* for Sustainable Biocement Production Using Hard Water

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Introduction

Biocementation, a microbial-based process for producing eco-friendly construction material. Biocement offers a sustainable and eco-friendly alternative to conventional cement by utilizing microbial-induced calcite precipitation instead of high-temperature chemical processes. It significantly reduces CO_2 emissions, energy consumption and production costs while enhancing material durability and self-healing properties. Moreover, it promotes environmental restoration and resource recycling, aligning with green construction and sustainable development goals (SDG 9; SDG 12, SDG 13, SDG 15).

Objectives

The aim of this study is (i) to explore potent urease-producing bacteria from marine sources as potential candidates for bio-cement production, (ii) to optimize various bioprocess parameters for enhanced bio-cement production and (iii) to utilize hard water for bio-cement production.

Methodology

Marine samples were collected aseptically and subjected to isolation for urease producing bacteria. Most potent bacterial isolate was selected based on urease producing and calcium carbonate precipitation capability. Afterwards, optimization of bioprocess parameters by selected bacterial culture for improved biocement production using OFAT approach was done. After each step, % yield of biocement was calculated.

Results

Total of 17 marine bacterial isolates were isolated and purified, and among them, only four cultures were able to hydrolyze urea. These isolates were further tested for their ability to precipitate calcium carbonate. Strain MW1 showed the highest calcium carbonate precipitation from hard water. Consequently, strain MW1 was selected for further study. The most potent strain MW1 was identified as Bacillus subtilis using 16S rDNA sequencing. Optimization studies showed that strain MW1 efficiently produced bio-cement at 35°C within 48 hours using 250 ml of hard water.

Conclusion & Recommendations

Bio-cement production through bio-cementation using urease-producing bacteria has emerged as a significant area of research, showing potential in various applications including construction and environmental remediation. This approach helps minimize the environmental impacts of the cement industry, including reduced energy consumption and lower CO2 emissions.

Keywords: Biocement, Bacillus, Hard water, SDG, Optimization

Rethinking Rural Finance for Climate-Smart Agriculture in Pakistan: Economic Pathways for Smallholder Adaptation

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Introduction

Pakistan's agriculture is highly exposed to climate risks such as heat stress, erratic rainfall, and floods, yet the transition toward climate-smart and sustainable farming remains slow and uneven. A major constraint is that most smallholder farmers face tight credit, insurance, and liquidity constraints, which limit their ability to invest in improved seeds, efficient irrigation, diversified cropping systems, and climate-resilient technologies.

Objectives

This study examines how access to rural finance influences the adoption of climate-smart agriculture (CSA) practices among smallholders in Pakistan and explores which economic pathways can make this transition both scalable and inclusive.

Methodology

The research combines secondary data from national agricultural and household surveys with primary survey data collected from smallholder farmers, input dealers, and credit providers in selected districts. Econometric analysis (e.g., probit/logit and regression models) is used to estimate the relationship between access to formal and informal credit, savings and insurance, farmers' risk perceptions, and the uptake of CSA practices. Qualitative interviews are used to explain why some farmers remain locked in low-investment, high-risk production systems despite being aware of climate risks.

Results

Preliminary analysis indicates that farmers with reliable access to tailored financial services are more likely to adopt water-saving technologies, diversify crops, and invest in soil and input management that enhance resilience. At the same time, high collateral requirements, information gaps, and weak links between financial institutions, extension services, and farmers reduce the effectiveness and outreach of existing schemes. Constraints are particularly binding for resource-poor and tenant farmers.

Conclusion & Recommendations

Conclusions/Implications The findings suggest that rural finance design is central to unlocking climate-smart investment at the farm level. Policy options such as blended finance, risk-sharing facilities, index-based insurance, and climate-linked credit scoring can realign incentives toward CSA adoption, especially for smallholders facing high climate risk. The study offers context-specific recommendations for policymakers, financial institutions, and development partners seeking to support climate-smart and sustainable agriculture in Pakistan.

Keywords: Climate-smart agriculture (CSA) Rural finance Smallholder farmers Credit and liquidity constraints Climate risk and resilience Index-based insurance Blended finance Pakistan agriculture

Financial Vulnerability and Risk Exposure in Small-scale Fisheries

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Introduction

Small-scale fisheries are important in food supply, employment, and rural livelihood in most developing areas. Nevertheless, there is a growing vulnerability of these systems to various risk factors such as climate change, market uncertainties, volatile input costs, and inaccessibility of financial facilities. These risks increase the financial risks of fishing families, as well as endangering the viability of small-scale fisheries.

Objectives

This paper will evaluate the type and level of risk exposure in small-scale fisheries and analyze its impact on the financial exposure of fishing families. In particular, the paper reviews the risks associated with production, market and climate conditions and the importance of financial access and risk coping strategies.

Methodology

The research is founded and grounded on the primary data that will be gathered through organized interviews with small-scale fishers using structured questionnaires and key informants. Descriptive statistics and econometric analysis were also used to determine key sources of risk and measure their impact on the variability of incomes, the level of debts, and financial stability of households.

Results

The results show that the small-scale fishers are highly exposed to climate and market risks, which lead to high levels of income insecurity and dependency on informal credit. Financial vulnerability is further enhanced by limited access to insurance, formal finance and institutional support. Fishers who have diversified sources of income and those who are able to access financial services demonstrate a comparatively reduced vulnerability.

Conclusion & Recommendations

Financial vulnerability in small-scale fisheries is still largely caused by risk exposure. Resilience may be enhanced by strengthening access to financial instruments, encouraging risk diversification approaches and enhancing institutional support to support the long-term sustainability of small-scale fisheries.

Keywords: Small-scale fisheries: Risk exposure; Financial vulnerability; Climate variability; Livelihood resilience.

Crop Yield Risk Assessment using CNN-SVM Integrated Deep Learning Framework

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Introduction

Agriculture is an essential contributor to the economy of a developing country where food self-sufficiency and resource conservation are largely dependent upon crop yield. Accurate prediction and risk evaluation of crop yield, which are useful for enhancing agricultural production and reducing financial loss due to climate and environment uncertainties are important. In general, the linear-based models do not accurately describe nonlinear climatic- soil-crop interactions. This research offers a CNN (Convolutional Neural Network)-SVM (Support Vector Machine) model to assess crop yield and risk.

Objectives

This work is dedicated to proposing a CNN-SVM integrated deep learning framework for crop yield analysis and risk classification problem. Its CNN module extracts deep features of various agronomic factors such as rainfall, temperature, soil pH and using SVM classifier categorizing the yield risk in three orders (High, Medium, Low).

Methodology

The study employs a quantitative research design using an integrated CNN–SVM framework on structured agricultural data, including rainfall, temperature, soil pH, and nutrient levels. Data preprocessing involves normalization and handling missing values. CNN automatically extracts deep features capturing complex variable interactions, which are subsequently classified by an SVM into high-, medium-, and low-yield risk categories. Model performance is evaluated using accuracy, precision, recall, and F1-score metrics.

Results

The experimental results demonstrate that the proposed CNN–SVM framework is highly effective for crop yield prediction and risk classification. CNN efficiently extracts deep and meaningful features from agronomic data, which significantly enhances the classification performance of the SVM. Compared with traditional machine learning models applied independently, the hybrid approach achieves superior accuracy and robustness. The SVM classifier performs well in distinguishing high-, medium-, and low-risk yield categories, with consistently high precision and recall across all classes. Overall, the findings confirm that integrating CNN-based feature extraction with SVM-based classification is well suited for structured agricultural data and supports reliable decision-making in crop yield risk assessment.

Conclusion & Recommendations

This study concludes that the CNN–SVM hybrid framework is an effective tool for crop yield risk analysis, accurately capturing complex relationships among agronomic factors and providing reliable risk classification. The model offers strong support for agricultural decision-making. Future research may incorporate weather forecasts, satellite imagery, and soil health indicators, extend application across diverse regions of Pakistan, and develop real-time or mobile-based decision support systems.

Keywords: Crop Yield Prediction, CNN-SVM Hybrid Model, Agronomic Factors, Risk Classification, Machine Learning in Agriculture

Impact of Corporate Tax Avoidance on Consumer Behavior

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Introduction

Corporate tax avoidance has become a critical ethical and economic concern in contemporary business practices. While legally permissible, aggressive tax avoidance strategies are often criticized for undermining corporate social responsibility (CSR), fairness, and societal contribution. With increasing access to information and media coverage, consumers are now more aware of corporate financial behavior and increasingly evaluate brands based on ethical standards in addition to price and quality. In Pakistan, where public revenues are essential for socioeconomic development, corporate tax avoidance carries significant social implications. This study investigates the impact of corporate tax avoidance on consumer behavior in Pakistan, focusing on consumer awareness, ethical perceptions, brand image, brand trust, purchasing decisions, and customer loyalty.

Objectives

The study aims to assess consumer awareness of corporate tax avoidance, examine its ethical perceptions, and analyze its influence on brand image and trust. It further explores how tax avoidance practices affect purchasing behavior and brand loyalty among consumers.

Methodology

A mixed-methods research design was employed, combining quantitative and qualitative approaches. Primary data were collected through a structured questionnaire administered to 40 adult consumers in urban areas of Pakistan using convenience sampling. The survey included Likert-scale and categorical questions to measure awareness, ethical judgments, trust, loyalty, and purchase intentions. Descriptive statistical techniques were used for data analysis. Secondary data from academic literature, policy reports, and media sources were reviewed to support and contextualize the findings.

Results

The results indicate that most respondents possess moderate to high awareness of corporate tax avoidance, largely driven by media exposure. Although tax avoidance is perceived as legal, it is widely regarded as unethical. The findings reveal a negative association between corporate tax avoidance and brand trust, with many consumers reporting diminished confidence in firms engaged in such practices. Ethical concerns influence purchasing decisions, increasing the likelihood of brand switching and reducing loyalty. However, some consumers remain loyal due to price sensitivity or strong brand attachment.

Conclusion and Recommendations

The study concludes that corporate tax avoidance adversely affects consumer trust, brand perception, and loyalty in Pakistan. Firms are encouraged to adopt transparent and socially responsible tax practices to enhance long-term consumer trust. Policymakers should promote greater corporate tax transparency and consumer awareness. Future research may expand the sample size and adopt longitudinal approaches to capture changing consumer perceptions.

Keywords: Corporate Tax Avoidance, Consumer Trust, Brand Perception, CSR, Purchasing Behavior, Brand Loyalty.

Economic Effects of High-Quality Wheat Seed Availability on Farm Productivity: Econometric Evidence from Mardan District, Khyber Pakhtunkhwa

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Introduction

High-quality seed is a critical input for improving crop productivity and enhancing farm-level economic performance, particularly for staple crops such as wheat in Pakistan. Despite the recognized benefits of certified and improved wheat varieties, their availability and adoption remain uneven across wheat-producing regions. These disparities constrain yield potential, limit income growth, and weaken food security outcomes, especially in areas dominated by small and medium-scale farmers. In Khyber Pakhtunkhwa, structural weaknesses in seed production, distribution, and regulation further exacerbate these challenges, underscoring the need for evidence-based analysis of seed-related productivity effects.

Objectives

This study aims to examine the economic effects of high-quality wheat seed availability on farm productivity in Mardan district of Khyber Pakhtunkhwa, Pakistan. The analysis seeks to assess the extent to which access to certified and improved seed varieties influences wheat yields and farm-level economic performance compared to the use of traditional or farm-saved seeds.

Methodology

An econometric analysis was conducted using secondary farm-level and district-level data obtained from official agricultural statistics and related sources. Wheat productivity was modelled as a function of seed quality and availability, along with conventional production inputs such as fertilizer, irrigation, labour, and relevant farm characteristics. Regression-based estimation techniques were applied to quantify the relative contribution of high-quality seed to productivity outcomes while controlling for other influencing factors.

Results

The findings provide strong empirical evidence that access to certified and improved wheat seed significantly enhances wheat yields and farm-level economic performance. The results also indicate that limitations in seed distribution systems, restricted market access, and affordability constraints hinder wider adoption, particularly among small and medium-scale farmers.

Conclusion & Recommendations

The study highlights the importance of strengthening seed supply chains, improving regulatory oversight, and promoting efficient and inclusive input markets to enhance wheat productivity in Khyber Pakhtunkhwa. Targeted policy interventions aimed at improving seed availability and affordability can facilitate wider adoption of high-quality seed and contribute to sustainable improvements in agricultural performance and rural incomes.

Keywords: High-quality seed, Wheat productivity, Agricultural economics, Seed availability, Econometric analysis, Khyber Pakhtunkhwa

Energy Governance and Public Policy Coordination: OPEC's Institutional Role in Global Oil Markets

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Introduction

The Organization of the Petroleum Exporting Countries (OPEC) has long been a key player in shaping how the global oil market functions. By bringing oil-producing countries together, OPEC coordinates petroleum policies aimed at maintaining market stability and protecting the economic interests of its members (OPEC, 2023). As an influential international institution, it plays an active role in managing oil supply, influencing price trends, and responding to shifting economic and geopolitical conditions (Goldthau & Witte, 2010). At a time marked by energy transition and increased market uncertainty, OPEC's institutional role remains essential for understanding how public policy coordination and energy governance operate at the global level (Yergin, 2011).

Objectives

This study seeks to understand how OPEC functions as an institution in coordinating energy policies among its members. It also aims to evaluate OPEC's effectiveness in stabilizing global oil markets and to examine its broader influence on international energy governance and public policy coordination.

Methodology

The study uses a qualitative case study approach based on secondary data. Information is drawn from OPEC publications, reports by international energy agencies, policy documents, and relevant academic literature. Content analysis is applied to examine OPEC's policy decisions, production agreements, and institutional arrangements. In addition, key oil market events are reviewed to provide comparative insights into OPEC's role in managing market volatility and coordinating energy policies within the global governance framework.

Results

The findings show that OPEC continues to be an important institutional actor in global oil governance, even as market conditions evolve. Coordinated production quotas and cooperation with non-OPEC producers have strengthened its ability to influence oil prices and limit extreme market fluctuations. However, differences in political and economic interests among member states, along with external challenges such as shale oil expansion and the shift toward renewable energy, have limited its overall effectiveness. The results suggest that OPEC is more successful in achieving short-term market stability than in shaping long-term outcomes. Its future influence largely depends on its ability to adapt policies, maintain institutional flexibility, and engage constructively with global energy transition efforts

Conclusion & Recommendations

In conclusion, OPEC remains a key institution in global energy governance by enabling collective decision-making among oil-producing countries. To remain effective, the organization should improve transparency in its decision-making processes and strengthen collaboration with non-member producers. Moreover, incorporating sustainability and energy transition concerns into its policy agenda will enhance OPEC's credibility. Aligning traditional oil market strategies with evolving global energy goals can help ensure its continued relevance and long-term governance effectiveness.

Keywords: Energy Governance, OPEC, Public Policy, Global Oil Markets, Institutional Coordination.

An Evaluation of Plant Protection Product Use and the Transition toward Agroecological Practices in Greenhouse Production within the Regulatory and Institutional Framework of Türkiye

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Introduction

Climate change has amplified the environmental and economic consequences of intensive chemical pesticide use in greenhouse production systems, raising concerns about the sustainability of chemically dependent production models. This has increased interest in agroecological practices, within which biopesticides play a strategic role by reducing environmental risks and enhancing food safety. Regulatory and institutional frameworks are therefore critical in shaping farmers' pest management decisions and the adoption of agroecological approaches.

Objectives

This study aims to examine plant protection product use patterns in greenhouse production in Türkiye, analyse the position of biopesticides within existing regulatory and institutional frameworks, and assess the effects of these regulations on the adoption of agroecological practices.

Methodology

A qualitative research design was employed, using document analysis as the primary method. At the European Union level, Regulation (EC) No. 1107/2009 on the authorization of plant protection products and Regulation (EC) No. 396/2005 on maximum residue limits were reviewed. In Türkiye, a comparative analysis was conducted of the Regulation on the Authorization and Placing on the Market of Plant Protection Products (Official Gazette No. 30695, 23 February 2019), the Regulation on the Recommendation, Application and Record-Keeping of Plant Protection Products (Official Gazette No. 29664, 25 March 2016), and the Regulation on Maximum Residue Limits in Plant Products (Official Gazette No. 28125, 27 November 2011).

Results

The findings indicate that biopesticides in Türkiye are regulated under the general plant protection product legislation and that the regulatory framework is largely harmonized with European Union legislation. Regulations on maximum residue limits and export market requirements encourage greenhouse producers to shift from chemical pesticides toward biological alternatives. However, the inclusion of biopesticides within general authorization procedures, coupled with limited incentive mechanisms, constrains the wider adoption of agroecological practices.

Conclusion & Recommendations

The current regulatory framework has the potential to support the environmental and economic benefits of biopesticides, but this potential is not fully realized in practice. The study highlights that the transition toward agroecological practices is a governance process shaped by regulatory and institutional structures rather than solely a technical choice. Simplifying authorization procedures for biopesticides, strengthening regulatory facilitation for low-risk products, and more explicitly linking agroecological practices with agricultural support policies are recommended to accelerate the climate-smart and sustainable transformation of greenhouse production systems.

Keywords: Agroecological Practices; Greenhouse Production; Biopesticides; Plant Protection Products; Agricultural Policies

Institutional Quality and Climate Vulnerability: Global Evidence from Dynamic Panel Analysis

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Introduction

Climate vulnerability has emerged as a major challenge to sustainable development, as countries are increasingly exposed to a wide range of environmental, social, and economic stresses. Institutional quality plays a vital role in mitigating the effects of climate shocks, as strong governance frameworks facilitate adaptation, resource management, and policy implementation. Despite extensive research on climate risks, there is limited empirical evidence linking governance and institutional performance directly to climate vulnerability across countries. Understanding this relationship is essential for designing effective public policies that enhance resilience and promote sustainable development.

Objectives

This study examines the impact of institutional quality on climate vulnerability globally, while controlling economic, demographic, and environmental factors, to identify policy-relevant drivers of resilience.

Methodology

The empirical analysis employs panel data for 117 countries over 2000–2022. An institutional quality index is constructed using principal component analysis of governance indicators, data from the World Bank. Climate vulnerability is proxied using the ND-GAIN index sourced from the Notre Dame Global Adaptation Initiative (ND-GAIN) database. System GMM estimation addresses endogeneity, dynamic persistence, and unobserved heterogeneity. Explanatory variables include GDP per capita, trade openness, population density, renewable energy consumption, and government expenditure. Robustness is checked using diagnostic tests for serial correlation and overidentifying restrictions, ensuring reliable inference.

Results

Results indicate strong persistence in climate vulnerability over time. Higher institutional quality significantly reduces vulnerability, demonstrating the protective role of effective governance. Economic development, measured by GDP per capita, also decreases vulnerability, whereas environmental pressures, including CO_2 emissions and temperature anomalies, increase exposure. Renewable energy consumption, trade openness, and population density show mixed effects. Government expenditure is negatively associated with vulnerability but not statistically significant. Diagnostic tests confirm instrument validity and have no evidence of second-order serial correlation, supporting the reliability of the System GMM estimates. These findings highlight both structural and governance factors as key determinants of climate resilience.

Conclusion & Recommendations

Institutional quality is a critical determinant of climate vulnerability, underscoring the need for strong governance and effective public institutions to manage climate risks. Policymakers should prioritize reforms that enhance transparency, accountability, regulatory quality, and government effectiveness. Integrating climate resilience into national development strategies, coupled with investments in renewable energy and sustainable urban planning, can reduce vulnerability. Strengthening institutions and governance frameworks provides a pathway for countries to adapt to climate change and achieve sustainable development goals.

Keywords: Climate Vulnerability; Institutional Quality; ND-GAIN Index; Dynamic Panel Data; System GMM

Impact of Women's Empowerment on Sustainable Development in District Faisalabad

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Introduction

Gender inequality continues to pose a major challenge to sustainable development in many developing economies, where women often face structural barriers in accessing education, employment, financial resources, and decision-making platforms. Despite constituting a substantial share of the population, women's contributions to economic growth and social progress remain underutilized. Increasingly, women's empowerment is recognized as a central pillar of sustainable development, as it enhances human capital formation, promotes inclusive economic growth, strengthens social cohesion, and supports environmentally responsible behaviour. Empowered women are more likely to invest in household welfare, children's education, health, and sustainable resource management. Understanding the multidimensional linkages between women's empowerment and sustainable development is therefore critical for designing effective policies that foster inclusive growth and long-term societal resilience.

Objectives

This study aims to examine the role of women's empowerment in improving household welfare, increasing income levels, strengthening social integration, and promoting environmental awareness in developing economies. It further seeks to identify the key socioeconomic, institutional, and cultural constraints that hinder women's empowerment and limit its contribution to sustainable development.

Methodology

The study adopts a quantitative research design based on primary data collected from women using a structured questionnaire. The survey captures information on education, employment, income, decision-making power, access to resources, and environmental awareness. Descriptive statistics will be used to summarize key characteristics of respondents, while appropriate regression techniques will be applied to empirically assess the impact of women's empowerment on economic, social, and environmental dimensions of sustainable development. Diagnostic tests will ensure the robustness and reliability of the estimated results.

Results

The findings are expected to show that women's empowerment has a statistically significant and positive impact on household welfare, income generation, social cohesion, and environmental awareness. Empowered women are anticipated to contribute more effectively to household decision-making, resource allocation, and community participation. However, persistent constraints such as limited access to education, financial services, productive assets, and leadership opportunities are expected to weaken the full realization of empowerment benefits and slow progress toward sustainable development.

Conclusion & Recommendations

The study is expected to provide strong empirical evidence in support of integrating women's empowerment into national and local development strategies. Policymakers should prioritize investments in women's education, financial inclusion, and leadership opportunities to unlock their development potential. Strengthening women's empowerment is essential for achieving inclusive, equitable, and environmentally sustainable development outcomes.

Keywords: Women's Empowerment, Sustainable Development, Gender Equality, Economic, Social and Environmental Dimensions

Estimation of Shadow Economy and its Impact on GDP of Pakistan

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Introduction
The shadow economy consists of economic activities that are deliberately concealed from public authorities to avoid taxation, social security contributions, and regulatory compliance. Such activities, while contributing to income generation and employment, pose serious challenges for economic governance and development. In Pakistan, the persistence of a large shadow economy undermines fiscal capacity by eroding tax revenues, distorts official economic statistics, and weakens the effectiveness of macroeconomic planning and policy formulation. A growing informal sector also reflects structural weaknesses in institutions, financial systems, and regulatory frameworks. Understanding the magnitude, determinants, and macroeconomic consequences of the shadow economy is therefore essential for designing effective fiscal, monetary, and financial sector reforms aimed at promoting inclusive and sustainable economic growth.

Objectives
This study aims to estimate the size of Pakistan's shadow economy and examine its impact on gross domestic product (GDP) and overall economic growth. Specifically, it seeks to analyse how monetary and financial variables associated with informality influence economic performance.

Methodology
The study adopts a quantitative research design using time-series data for Pakistan. Advanced econometric techniques, including the Ordinary Least Squares (OLS) method, are employed to analyse the dynamics of the shadow economy using the monetary approach and currency demand equations. To assess the impact of the shadow economy on economic growth, key variables such as interest rates, banking services, tax evasion, shadow economy size, and foreign remittances are incorporated into the model. Diagnostic and robustness tests are applied to ensure the validity and reliability of the estimated results.

Results
The empirical findings indicate that interest rates, banking services, tax evasion, the shadow economy, and foreign remittances significantly influence Pakistan's economic growth. The results suggest that higher interest rates, limited banking services, and an expanding shadow economy exert a negative impact on economic growth, reflecting reduced investment, financial exclusion, and loss of fiscal resources. In contrast, tax-related variables and foreign remittances show a positive association with economic growth, highlighting the role of external income inflows and fiscal linkages. The growth rate itself is found to have an insignificant direct effect on economic growth, indicating underlying structural constraints.

Conclusion & Recommendations
The study concludes that Pakistan's shadow economy is substantial and persistent, operating alongside the formal economy while significantly undermining fiscal stability and economic performance. Fluctuations in the shadow economy are closely linked to changes in GDP, with economic downturns often triggering an expansion in informal activities due to increased tax evasion and regulatory avoidance. To address these challenges, policymakers should strengthen tax administration, expand access to formal banking services, reduce excessive regulatory burdens, and promote financial inclusion. Such measures can help integrate informal activities into the formal economy, enhance revenue mobilization, and support sustainable economic growth.

Keywords: Shadow Economy, Interest Rate, Banking Services, Currency Demand Equation, Ordinary Least Squares

Exploring Indigenous Microbial Solutions for Bioremediation of Textile Dye Effluents and Mitigating their Phytotoxicity

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Introduction

The trend of urbanization and industrialization has granted the world with a lot of applicable and remarkable benefits. Along with the various advantages it also brings some issues and the revolution of industry comes with environmental problems. Like other industries, development in textile industry has brought the contamination of soil and water with effluent dyes, therefore treatment of dye-contaminated wastewater discharged from the textile and other dye-stuff industries is necessary to prevent contamination of soil surface and ground water. The cost-effective biological strategy is the need of time to complete mineralization of organic pollutants.

Objectives

The objectives of the research are to isolate the indigenous bacteria from the effluent; screen the isolated bacteria for their effluent degradation potential; optimize the different parameters for their effluent degradation potential; and treated effluents check for their phytotoxic effect onto seed germination and plant growth.

Methodology

Indigenous effluent degrading bacteria were isolated from different sources like discharged effluent and soil samples. Isolates were identified by microbiological and biochemical tests. The effluent degradation potential of identified isolates was confirmed by calorimetric analysis. Different parameters (pH, Incubation time, temperature) were optimized. Treated effluent were also used for their phytotoxic effect by using Vigna radiata (Moong Beans) and Triticum aestivum (Wheat).

Results

In present study the total forty bacteria were isolated and among them the six potential bacterial cultures showed maximum decolorization for dye containing effluent (Reactive black-5, RBR and Reactive Green). The dye effluents decolorizing isolates were showed their activity in 72hours of incubation and at pH 7-8, temprature30-40C. The treated effluent showed no adverse effect on plant growth and seed germination. These isolates could be effectively used as an alternative to physical and chemical processes for effluent treatment.

Conclusion & Recommendations

The traditional methods for the treatment of waste effluents are very expensive and require continuous investment in chemicals and energy. So, these methods become uneconomical and cause further environmental deterioration. Hence the bioremediation of textile effluents is more environmental and economically friendly method and can be applied for wastewater treatment. Thus, in present study it was concluded that the use of indigenous bacteria for wastewater treatment is attractive and sustainable approach.

Keywords: Dye decolorization, Effluents, Azoic dyes, Phytotoxicity

An Analysis of Income Inequality and Its Impact on Household Consumption and Ecological Footprints

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Introduction
Pakistan is an ecologically deficit country, consuming natural resources at a rate that exceeds its biological carrying capacity. Rapid population growth, urban expansion, rising household incomes, and increasingly resource-intensive consumption patterns have intensified pressure on land, energy, water, and ecosystems, resulting in widespread environmental degradation. While policy debates often focus on industrial and agricultural pressures, household consumption behavior remains a critical yet underexplored driver of environmental stress. Understanding how everyday household decisions translate into ecological impacts is essential for designing effective sustainability and climate-smart development strategies.

Objectives
This study examines the relationship between socio-economic characteristics, household consumption patterns, and ecological footprints in Faisalabad, Pakistan, with the aim of identifying key behavioral and economic determinants of household-level environmental pressure.

Methodology
Primary data were collected through a structured household survey conducted in Faisalabad. Household consumption behavior was assessed across major dimensions, including food consumption patterns, transportation modes, income levels, housing size, and electricity usage. Ecological footprints were estimated using a standardized online ecological footprint calculator. The empirical analysis employed descriptive statistics to summarize consumption patterns, while correlation analysis, multiple linear regression, chi-square tests, and Eta tests were used to identify and quantify the socio-economic and behavioral factors influencing household ecological footprints.

Results
The findings show that household income, education, housing characteristics, and electricity consumption significantly increase ecological footprints, indicating a disproportionate environmental impact among higher-income and better-educated households. Larger housing units and higher energy use emerged as major drivers of resource consumption. Conversely, environmentally responsible behaviors, including recycling, waste segregation, and carpooling, were associated with lower ecological footprints. Dietary patterns also mattered, as higher meat consumption increased environmental pressure, while greater daily waste generation further intensified impacts. Overall, results highlight strong links between economic status, lifestyle choices, and household environmental outcomes nationwide.

Conclusion & Recommendation
The study concludes that improving environmental sustainability in Pakistan requires targeted policy interventions that influence household consumption behavior, particularly among affluent urban households. Promoting energy efficiency, sustainable housing design, waste reduction, recycling initiatives, and environmentally responsible lifestyle choices is essential for reducing ecological footprints. Integrating behavioral change strategies with urban planning and environmental policies can contribute to long-term resource efficiency and climate-smart sustainability.

Keywords: Income inequality; consumption behavior; Ecological footprint; Sustainable livelihoods; Energy use

Value Chain Analysis of Poultry: The Case of District Faisalabad

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Introduction
The poultry sector is a vital sub-sector of livestock and plays a significant role in Pakistan's agricultural economy. Poultry farming began to develop rapidly in Pakistan during the 1960s, largely due to supportive government policies aimed at promoting poultry production. The Government of Pakistan facilitated growth by exempting the sector from import duties, income tax, and sales tax, leading to substantial expansion during the 1970s and 1980s, with an average annual growth rate of approximately 30 percent. While commercial poultry production has expanded considerably over the past three decades, rural and small-scale poultry farming continues to hold substantial importance. It remains a major source of affordable animal protein for rural households and contributes to food security. Despite its importance, inefficiencies in production and marketing within small- and medium-scale poultry operations require empirical investigation.

Objectives
The main objective of this study is to analyze the production and marketing aspects of small and medium-scale broiler poultry farming, with a focus on understanding cost structures and value chain components.

Methodology
The study is conducted in Samundri, district Faisalabad. Primary data is collected from 200 respondents using a well-structured questionnaire, and a simple random sampling technique was employed. Regression analysis is applied using appropriate statistical tools to examine production and marketing costs and related factors in the broiler industry.

Results
The findings revealed that small and medium scale poultry farming plays a crucial role in supplying low-cost meat to rural populations. Rural poultry contributes significantly to the overall poultry production system and supports household food security. However, variations in production efficiency and marketing practices affect profitability across different scales of operation.

Conclusion & Recommendations
The study concludes that small and medium-scale poultry farming remains an essential component of Pakistan's poultry sector, particularly in rural areas. Strengthening the poultry value chain through improved production practices, cost management, and efficient marketing strategies can enhance productivity and income generation, while ensuring affordable protein availability for rural households.

Keywords: Poultry farming, value chain, value addition, marketing, value chain mapping

Informal Food Markets, Public Health Risks, and Economic Costs in Pakistan

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Introduction

The rapid expansion of informal food markets and services has significantly altered dietary patterns and public health outcomes in developing countries such as Pakistan. These unregulated food systems, including street vendors, roadside stalls, and informal food lounges, offer convenient and low-cost meals that meet immediate consumption needs but often lack nutritional quality and safety standards. The widespread availability of calorie-dense, nutrient-poor foods has contributed to the growing burden of non-communicable diseases (NCDs) such as obesity, hypertension, and diabetes. Beyond health impacts, the shadow economy of food markets imposes substantial developmental costs by increasing healthcare expenditures, reducing labour productivity, and constraining fiscal capacity, thereby undermining sustainable economic development.

Objectives

The objectives of this study are to examine the growth of informal food markets in Pakistan, analyse the relationship between low-cost food consumption and lifestyle-related health risks, assess the resulting economic and developmental costs, and propose policy recommendations for regulating food markets and promoting healthier consumption patterns.

Methodology

A cross-sectional survey and semi-structured interviews were conducted among 200 consumers and informal food vendors using structured questionnaires. Data were collected on food consumption behavior, frequency of informal food intake, self-reported health conditions, and household healthcare expenditures. Descriptive statistics and correlation analysis were applied to assess associations between informal food consumption and health risks. A mixed-methods approach was adopted by integrating quantitative survey findings with qualitative insights from national health reports and policy documents to provide a comprehensive understanding of the issue.

Results

The findings revealed a strong positive correlation between frequent consumption of informal foods and the prevalence of non-communicable diseases, particularly obesity, hypertension, and diabetes. Urban respondents were more vulnerable to lifestyle-related health problems than rural respondents due to higher exposure to informal food outlets and aggressive food marketing. Key drivers of informal food consumption included affordability, convenience, extensive promotional strategies on media platforms, and limited awareness of nutritional values. The proliferation of informal markets was also linked to weak regulatory frameworks and insufficient enforcement of food safety laws. These factors contribute to rising healthcare costs and divert public resources away from productive developmental investments.

Conclusion & Recommendations

The study concludes that informal food markets are a significant contributor to the increasing burden of non-communicable diseases in Pakistan. Addressing this challenge requires coordinated policy interventions, including stronger regulation of informal food markets, restrictions on unhealthy food advertising, and widespread nutrition education initiatives. Promoting sustainable diets and informed food choices is essential for reducing healthcare costs, improving public health outcomes, and supporting long-term economic development.

Keywords: Public Health, Informal Markets, Unhealthy Food

Impact of Urbanization on Agricultural Production and Food Insecurity

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Introduction

Rapid population growth has accelerated urban expansion, often encroaching on productive agricultural land. In developing economies such as Pakistan, unplanned urbanization contributes to serious challenges including pollution, climate change, traffic congestion, deforestation, and declining agricultural capacity. These pressures threaten food security and environmental stability, particularly in Punjab, a key agricultural region.

Objectives

This study aims to examine the impact of urbanization on agricultural production, food insecurity, and the climatic dynamics of Punjab. It further seeks to identify the key drivers linking urban growth with changes in food availability, accessibility, and production sustainability.

Methodology

The study will utilize secondary data from national and international sources covering the period 1990–2024. Econometric analysis will be conducted using the Autoregressive Distributed Lag (ARDL) model and the Error Correction Model (ECM). A climate change index will also be incorporated to assess how climate dynamics interact with urbanization and agricultural productivity.

Results

The expected findings will highlight how unplanned urbanization adversely influences agricultural output, exacerbates food insecurity, and interacts with climatic variability. The results are anticipated to provide deeper insights into the mechanisms through which urban growth affects food systems and production sustainability in Punjab.

Conclusion & Recommendations

By identifying the major determinants of agricultural production and food insecurity, this study will contribute to the literature on sustainable urban and rural planning. The research aims to offer evidence-based recommendations for policymakers to design effective strategies addressing agricultural sustainability, food security, and climate resilience. Ultimately, the study seeks to support a productive, sustainable, and resilient agricultural sector in Punjab amidst ongoing urbanization challenges.

Keywords: Urbanization, agricultural land, agricultural production, food insecurity, climate

Rural Women's Contribution to Household Food Security in Agrarian Communities: A Cross-Sectional Study from Rural Punjab, Pakistan

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Introduction

This study examines gendered pathways to household food security through a comparative analysis of women's roles in rural and urban households in Punjab, Pakistan. Women are central to household food security, contributing through food production, purchasing, preparation, storage, and intra-household distribution. Their responsibilities often extend to managing dietary diversity and coping strategies during food shortages. Despite their critical contributions, women's roles remain largely undervalued and constrained by entrenched patriarchal norms, socio-economic inequalities, and limited access to education, financial resources, land ownership, and decision-making authority. These constraints vary significantly between rural and urban contexts, where differences in livelihoods, market access, and social structures shape women's capacity to influence food security outcomes. Understanding these contextual differences is essential for designing effective, gender-responsive food security policies.

Objectives

The study seeks to examine how gendered roles, responsibilities, and constraints influence household food security outcomes in rural and urban settings. Specifically, it aims to compare women's contributions to food security, assess disparities in access to resources and decision-making power, and analyse how these factors shape food availability, access, utilization, and stability across different household contexts.

Methodology

A quantitative research design will be adopted to assess women's contributions and constraints related to household food security. Primary data will be collected using a structured interview schedule administered to 384 married women. Stratified sampling will ensure equal representation from rural and urban households. The study will be conducted in three purposively selected districts of central Punjab, chosen for their demographic, economic, and social diversity. Data analysis will be carried out using SPSS, employing descriptive statistics to summarize key variables and inferential techniques, including correlation and regression analysis, to examine relationships between women's roles, resource control, decision-making authority, and household food security practices.

Results / Expected outcomes

The study is expected to reveal that structural and cultural factors such as unequal access to education, income, land, and decision-making create distinct food security patterns between rural and urban households. Greater levels of women's empowerment and control over productive and financial resources are anticipated to be positively associated with improved household food security, dietary diversity, and resilience.

Conclusion & Recommendation

The findings will deepen understanding of gender food security linkages in developing-country contexts. Evidence generated by the study will support policymakers and development practitioners in designing gender-sensitive, context-specific interventions to enhance household food security and promote women's empowerment in Punjab, Pakistan.

Keywords: Food security; gender; women's role; rural and urban households; Punjab; Pakistan

Gendered Livelihoods and Household Food Security: Evidence from Rural Agricultural Communities in Punjab

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Introduction
Food insecurity remains a pressing development issue in many low- and middle-income countries. In Pakistan's rural communities, women bear substantial responsibility for ensuring household food security through food production, access, utilization, and overall resource management. Despite their vital contributions, there is limited empirical research exploring the role of rural women in household-level food security in the Pakistani context.

Objectives

This study aims to examine the extent of rural women's involvement in various dimensions of household food security in agrarian communities of Punjab, Pakistan.

Methodology
A cross-sectional quantitative survey was conducted in three purposively selected districts of Punjab. Data were collected from 420 rural households using a structured interview schedule and random sampling technique. Both descriptive and inferential statistics, including binary logistic regression, were applied to analyse the data.

Results / Expected outcomes
Findings showed that 49% of households were food insecure, while 51% were food secure. Women played a significant role across all dimensions of food security. In terms of availability, 67% of women contributed as farmers and labourers. For access, 57.4% acted as food buyers, and 23% were engaged in wage-based income generation particularly vital for low-income households. In food utilization, 75% of women were involved in food preparation, processing, and distribution. However, only 15.2% had substantial knowledge of nutritional needs. Additionally, 40.5% of the women were illiterate, and the majority (39.8%) were between 25–35 years of age. The binary logistic regression analysis indicated that women's participation in food production, indigenous knowledge, income contribution, age, education level, household size, and asset ownership were significant predictors of household food security.

Conclusion & Recommendation
The study concludes that rural women play a pivotal role in ensuring household food security. However, their contributions are often constrained by limited resources, education, and institutional support. Policy interventions should focus on empowering women through income-generating activities, nutritional education, and improved access to resources. Strengthening women's capacities will enhance household food security outcomes and contribute to broader rural development goals.

Keywords: Rural women, food security, agriculture, Punjab, Pakistan

Food Security, Livelihoods and Gender Inclusion in Pakistan: Advancing Sustainable and Equitable Food Systems

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Introduction

Pakistan is an agrarian country where a large proportion of the population, particularly in rural areas, depends on agriculture for employment and livelihoods. Despite considerable agricultural potential, food security remains a major challenge due to rapid population growth, socio-economic inequalities, climate variability, and inefficient food distribution systems. High levels of malnutrition, regional disparities in food availability, and unequal access to productive resources persist. Rural livelihoods are highly vulnerable to climatic shocks, volatile markets, limited credit facilities, low technological adoption, and inadequate infrastructure. Gender inequality further exacerbates these challenges. Women play a critical role in agricultural production, food preparation, and household nutrition, yet they face limited decision-making power, restricted land ownership, and poor access to education, extension services, and financial resources. Addressing food insecurity therefore requires an integrated approach that considers gender inclusion, livelihood diversity, and climate resilience within Pakistan's agri-food systems to promote sustainable and equitable development.

Objectives

This study investigates the relationship between agri-food systems, gender inclusion, livelihood sustainability, and food security in rural Pakistan. The objectives are: (1) to assess women's contributions to household and community food security; (2) to identify gender-based barriers to accessing markets, technologies, and productive resources; and (3) to propose gender-responsive policy measures to enhance food security and economic resilience.

Methodology

A mixed-methods approach was adopted using primary and secondary data. Primary data were collected through structured household surveys (n = 320) and focus group discussions (n = 10) conducted in selected districts of Punjab. Food security and livelihood conditions were assessed using the Food Insecurity Experience Scale (FIES) and the Sustainable Livelihoods Framework (SLF). Gender inclusion indicators included women's access to land, credit, extension services, and participation in decision-making. Qualitative data were analyzed thematically using NVivo 14, while quantitative data were analyzed using SPSS 26.

Results / Expected outcomes

Women constitute nearly 49% of the rural agricultural workforce, yet fewer than 10% own land. Households with greater female participation in decision-making report improved food security and dietary diversity. Persistent gender gaps in finance, inputs, and information limit productivity. Gender-inclusive cooperatives show positive impacts on income, nutrition, and resilience.

Conclusion & Recommendation

Gender inclusion is essential for achieving sustainable livelihoods and food security in Pakistan. Empowering women through equitable access to resources, services, and decision-making strengthens resilient and sustainable food systems.

Keywords: Food security, livelihoods, gender inclusion, agriculture, food systems, sustainability

Women at the Core of Climate-Smart Agriculture: Advancing Equity and Food Security through Empowerment

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Introduction
Climate change poses a major threat to agricultural productivity and food security, particularly in developing regions where women are central to smallholder farming and household nutrition. Despite their vital role, gender disparities in access to land, credit, and technology continue to limit women's adaptive capacity. Integrating gender equity within climate-smart agriculture (CSA) is essential to achieving inclusive, sustainable, and resilient food systems. This review examines existing evidence on how empowering women through CSA enhances productivity, resilience, and food security while promoting social justice in climate-affected rural communities.

Objectives
To review and synthesize current literature on women's empowerment in climate-smart agriculture, identifying how gender-responsive strategies contribute to sustainable livelihoods, improved resilience, and food security outcomes in developing countries.

Methodology
A structured narrative review was conducted using the PRISMA framework. Peer-reviewed articles, policy briefs, and reports published between 2010 and 2024 were retrieved from Scopus, Web of Science, PubMed, and Google Scholar. Search terms included "women empowerment," "gender equity," "climate-smart agriculture," and "food security." Selected studies were analysed thematically across three dimensions: (1) women's participation and resource access, (2) adoption of CSA practices, and (3) food security and livelihood outcomes.

Results / Expected outcomes
The review highlights that women's empowerment strongly correlates with improved agricultural productivity, adaptation, and nutrition. When women gain decision-making power and access to training or financial resources, adoption of CSA practices such as crop diversification, efficient irrigation, and organic soil management increases significantly. However, persistent barriers including limited land rights, restricted mobility, and gender bias constrain progress. Successful interventions emphasize gender-inclusive extension services, leadership training, and microfinance access as key enablers of equitable and climate-resilient food systems.

Conclusion & Recommendations
Empowering women is central to climate-smart and sustainable agriculture. Integrating gender equity into CSA policies, enhancing access to education, technology, and finance, and strengthening institutional support can foster resilient livelihoods and equitable food security in climate-affected regions.

Keywords: Gender equity, Climate-smart agriculture, Food security, Women empowerment, Sustainable livelihoods

Food Security and Livelihood Challenges in Pakistan: A Review of Current Trends and Determinants

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Introduction

Food security and livelihood stability are central to sustainable development, particularly in countries experiencing climate variability, economic pressures, and rapid population growth. Pakistan has increasingly faced food insecurity due to recurring climate shocks, rising inflation, and socio-economic vulnerabilities. Food security involves four key dimensions: availability, access, utilization, and stability of food. These dimensions are closely linked with income levels, employment opportunities, and access to markets. Understanding the current food security situation and its underlying drivers is essential for policymakers and development practitioners to design effective and inclusive interventions.

Objectives

This review aims to assess the status of food security and livelihoods in Pakistan, identify key determinants, and highlight major trends and policy implications based on evidence from national and international sources.

Methodology

This study is based on a qualitative review of recent national surveys, government publications, and international assessment reports related to food security and livelihoods in Pakistan. Key data sources include the Pakistan Social and Living Standards Measurement (PSLM) surveys, reports from the Food and Agriculture Organization (FAO), the Integrated Food Security Phase Classification (IPC), and sub-national food systems dashboards. The reviewed literature was analysed to identify common patterns, drivers, and regional disparities affecting food security and livelihood outcomes.

Results

Recent evidence indicates that a substantial share of Pakistan's population faces food insecurity and poor nutritional outcomes. According to the Pakistan Food Systems Dashboard, about 18.5 percent of the population is undernourished, while 12.9 percent is severely food insecure and 42.3 percent is moderately food insecure. Furthermore, the FAO Global Report on Food Crises (2025) estimates that nearly 11 million people, representing 22 percent of the analyzed population, experienced high levels of acute food insecurity between November 2024 and March 2025, with approximately 1.7 million people in emergency conditions. Household-level data from the PSLM survey shows that around 16 percent of households experienced moderate to severe food insecurity. These findings highlight strong regional disparities and increased vulnerability driven by climate extremes, inflation, and limited livelihood opportunities.

Conclusion & Recommendation

Food security and livelihood challenges in Pakistan are shaped by climate variability, economic instability, and structural inequalities. A significant proportion of the population remains vulnerable to food insecurity, with serious implications for health, productivity, and overall wellbeing. Policy efforts should prioritize strengthening social protection systems, improving access to markets and income opportunities, promoting climate-resilient agricultural practices, and investing in nutrition-sensitive interventions. Regular monitoring using updated data and region-specific strategies is essential to achieve sustainable food security and resilient livelihoods.

Keywords: Food security, Undernourishment, Livelihoods, Pakistan, Nutrition

Design and Development of Lab-scale Food Dehydrator for Energy-efficient and Sustainable Food Preservation

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Introduction

Food dehydration is one of the most effective preservation techniques used to extend shelf life while retaining nutritional quality, sensory attributes, and safety of food products. A lab-scale dehydrator provides a controlled environment to study drying behaviour and optimize process parameters before scaling up for industrial applications. This thesis focuses on the design and development of a lab-scale food dehydrator intended for experimental and educational purposes. The study emphasizes evaluating the operational performance of the dehydrator, particularly its ability to efficiently remove moisture while maintaining the physicochemical integrity of various food materials. By examining drying characteristics under controlled conditions, the research contributes to improving sustainable food preservation methods.

Objectives

The lab-scale dehydrator was designed for small-scale food processing, research experimentation, and product development in food technology laboratories. The primary objectives were to evaluate the thermal efficiency of the dehydrator, determine drying rates of selected food commodities, and assess the impact of dehydration on key physicochemical properties such as moisture content and quality retention. The study also aimed to compare drying behaviour across different food matrices.

Methodology

Drying experiments were conducted on a range of food commodities, including thick, thin, leafy, and liquid food products. Solid samples such as carrot, cucumber, cucumber peel, potato, spinach, mint, and tomato peel were prepared uniformly and dried under constant airflow conditions. Liquid foods, including raw milk and fruit juice, were also dehydrated using suitable trays. Drying temperature was maintained consistently throughout the experiments. Moisture loss was measured at regular intervals to calculate drying rate, moisture ratio, and drying time. High-moisture commodities required longer drying durations compared to low-moisture products such as herbs.

Results

The results showed that carrot slices, cucumber slices, cucumber peel, potato slices, spinach, tomato peel, milk, and fruit juice achieved complete drying within approximately 120 minutes, while mint dried fully within 60 minutes. Moisture content decreased steadily over time, enabling accurate calculation of drying kinetics. Drying at 60°C was found to provide an optimal balance between reduced drying time and quality retention.

Conclusion & Recommendations

The study concludes that the developed lab-scale dehydrator is effective for experimental analysis of drying behaviour and optimization of drying parameters. Its performance closely resembles pilot-scale systems, making it suitable for food research, training, and development of sustainable postharvest processing technologies.

Keywords: Food dehydrator; Drying rate; Thermal efficiency; Food preservation; Sustainable processing

Study on Biodegradable Plastic Made from Soluble Polysaccharides with Incorporation of EOs and Study its Effectiveness on Food Commodity

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Introduction

The increasing use of conventional plastic packaging in the food industry has raised serious environmental and health concerns due to its non-biodegradable nature and long persistence in ecosystems. Consequently, there is a growing demand for sustainable alternatives that can reduce plastic waste while maintaining food quality and safety. Bioplastics derived from natural polymers have emerged as a promising solution, particularly for food packaging and wrapping applications aimed at extending shelf life. In addition to their biodegradable nature, bioplastics can be functionalized with bioactive compounds to enhance preservation performance. Previous research has demonstrated that essential oils (EOs) possess strong antimicrobial and antioxidant properties and are effective in reducing ethylene production, which plays a critical role in fruit ripening and senescence. Incorporating essential oils into bioplastic matrices therefore offers a dual advantage of environmental sustainability and improved food preservation.

Objectives

The primary objective of this study was to develop bioactive bioplastic films using soluble polysaccharides incorporated with essential oils, specifically lemon oil and cinnamon oil. The study further aimed to evaluate the effectiveness of these films in extending the shelf life of tomatoes by slowing ripening, reducing microbial growth, and maintaining overall quality during storage.

Methodology

Bioplastic films were prepared using varying ratios of soluble polysaccharides combined with lemon oil and cinnamon oil as active components. These essential oils were selected due to their known antimicrobial, antioxidant, and ethylene-inhibiting properties. The prepared films were subjected to qualitative and quantitative analyses to assess their physical and functional characteristics. Film dimensions and properties were standardized and recorded, including surface area (12.5 cm^2), thickness (0.611 mm), specific gravity (0.01825), and density (0.0182 g/ml). Shelf-life studies were conducted using tomatoes at different maturity stages, and the performance of bioactive films was compared with that of standard packaging films.

Results

The analytical results showed a positive response when compared with findings from previous studies. Tomatoes coated with bioactive bioplastic films exhibited delayed ripening, reduced spoilage, and better-quality retention relative to those wrapped in conventional films. The incorporation of essential oils significantly enhanced the preservation effect, demonstrating the films' ability to extend tomato shelf life.

Conclusion & Recommendations

The study concludes that bioplastic films developed from soluble polysaccharides and enriched with lemon and cinnamon essential oils are effective in enhancing food preservation. These bioactive films represent a viable, eco-friendly alternative to conventional plastics, offering benefits in food safety, shelf-life extension, and environmental sustainability. Further research is recommended to scale up production and evaluate commercial feasibility.

Keywords: Bioplastic; Shelf life; Antimicrobial property; Antioxidant property; Food safety

Optimizing Probiotic Bioavailability in Ginger Soda via Ginger Bug Culture Enhancement

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Introduction

The rising demand for affordable, health-enhancing beverages has driven significant innovation within the food and fermentation industries. Ginger bug, a naturally fermented and lightly carbonated drink, is valued for its distinctive ginger flavour and probiotic potential, particularly for supporting gastrointestinal health. Incorporating additional functional ingredients, such as lemon and specific probiotic strains, may further enhance its nutritional and therapeutic properties.

Objectives

This study aims to develop a probiotic-rich, ginger-based carbonated beverage infused with lemon by utilizing the synergistic effects of *Lactobacillus plantarum* and *Lactobacillus bulgaricus*. The goal is to formulate a refreshing, functional drink that combines the bioactive compounds of ginger with the established health benefits of probiotics, particularly for digestive health and immune support.

Methodology

A ginger bug starter culture was developed using fresh ginger, sugar, and water through natural fermentation. Controlled inoculation with *Lactobacillus plantarum* and *Lactobacillus bulgaricus* was introduced to enhance probiotic density. Lemon infusion was added to improve flavour and nutritional value. The beverage underwent a monitored fermentation process, and assessments were conducted for carbonation level, sensory attributes, probiotic viability, and overall nutritional profile.

Results

The formulated beverage demonstrated successful fermentation, achieved desirable carbonation, a balanced flavour profile, and high probiotic viability. The combined action of the selected Lactobacillus strains enhanced the functional properties of the drink, contributing positively to its potential gastrointestinal and immune-supportive benefits. Sensory evaluation indicated strong acceptance due to the refreshing ginger–lemon flavour.

Conclusion & Recommendations

The study concludes that the ginger–lemon probiotic beverage offers a cost-effective, nutritious, and appealing alternative to conventional soft drinks. Its rich probiotic content and bioactive components make it suitable for promoting digestive wellness and immune health. Further research is recommended to evaluate shelf stability, optimize large-scale production, and assess specific health outcomes through clinical studies.

Keywords: Probiotic Beverage, Ginger Bug Fermentation, Lactobacillus plantarum, Functional Foods, Gastrointestinal Health

Development of a Functional Focaccia Soft Bread with Spinach Powder and Other Nutritious Ingredients

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Introduction

Growing consumer awareness regarding the relationship between diet and health has significantly increased demand for nutritious, affordable, and functional food products. Functional foods not only provide basic nourishment but also offer additional health benefits that can help prevent nutritional deficiencies and lifestyle-related diseases. Bakery products, particularly bread, are ideal carriers for functional ingredients due to their widespread consumption across different age groups and socio-economic segments. Fortifying commonly consumed bakery items allows for improved nutrient intake without requiring major dietary changes. Spinach (*Spinacia oleracea*), a leafy green vegetable, is a rich source of iron, dietary fiber, vitamins A, C, and K, folate, and bioactive antioxidants. Incorporating spinach into baked products presents a promising strategy to enhance micronutrient content, improve antioxidant intake, and support overall dietary quality. However, maintaining sensory acceptability and desirable texture remains a key challenge in functional bakery product development.

Objectives

This study aimed to develop a functional soft focaccia bread enriched with spinach powder and other nutrient-dense ingredients. The specific objective was to enhance the nutritional profile of the product while preserving desirable sensory attributes, texture, and consumer acceptability.

Methodology

Spinach leaves were processed into powder and incorporated into a soft focaccia bread formulation alongside additional wholesome ingredients selected for their nutritional and functional properties, including support for digestive health and antioxidant activity. Standard baking procedures were followed to ensure product consistency. Proximate analysis was conducted to determine moisture content, ash, fat content, and pH using established analytical methods. Sensory evaluation was performed using a structured hedonic scale to assess attributes such as taste, aroma, texture, appearance, and overall acceptability among panelists.

Results

The developed functional focaccia bread demonstrated favorable physicochemical and sensory characteristics. The low moisture content (2.62%) suggests improved shelf stability and reduced risk of microbial spoilage. The ash content (1.29%) indicated enhanced mineral content, attributable to spinach fortification. Low fat content (0.42%) makes the product suitable for health-conscious consumers, while the neutral pH confirms product safety. Sensory evaluation scores consistently exceeded 7, reflecting high consumer acceptability and confirming that nutritional enrichment did not adversely affect palatability.

Conclusion & Recommendations

The study successfully developed a spinach-enriched functional focaccia bread that combines improved nutritional value with strong sensory appeal. This product offers a practical, cost-effective, and health-oriented bakery alternative suitable for daily consumption. Further research may explore shelf-life extension and fortification with additional functional ingredients.

Keywords: Functional Focaccia; Spinach Powder; Nutritional Enhancement; Sensory Evaluation; Consumer Acceptance

Utilization of Pomegranate (Punica Granatum) and Apple (Malus Domestica) Peel Powder for the Development of Antioxidant-Enriched Fruit Bars: A Functional Food Perspective

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Introduction
Substantial quantities of fruit peels are generated annually as waste by households, food markets, and food-processing industries, contributing to environmental burden despite their high nutritional potential. These by-products are often discarded even though they are rich sources of bioactive compounds, dietary fiber, and natural antioxidants. Pomegranate (*Punica granatum*) and apple (*Malus domestica*) peels are particularly notable for their high concentrations of polyphenols, flavonoids, and other phytochemicals associated with antioxidant, anti-inflammatory, and disease-preventive properties. In recent years, growing consumer demand for functional foods and sustainable production systems has encouraged the valorization of agro-industrial waste into nutritionally enriched products. Utilizing fruit peels as functional ingredients not only enhances the nutritional profile of food products but also supports waste reduction, resource efficiency, and circular economy principles. Developing value-added snack products from fruit peel powders presents a practical opportunity to improve public health while promoting environmentally responsible food processing.

Objectives
This study aimed to utilize pomegranate and apple peels as functional ingredients for the development of a nutritious, antioxidant-rich fruit bar. The specific objectives were to reduce food waste, enhance the phytochemical and nutritional quality of snack products, and assess consumer acceptability of peel-fortified formulations.

Methodology
Fresh pomegranate and apple peels were collected, cleaned, dried, and ground into fine powders. These powders were incorporated into a fruit bar formulation at optimized levels to improve nutritional value and antioxidant capacity. The developed fruit bars were analyzed for proximate composition and phytochemical content, with particular emphasis on total phenolic and flavonoid concentrations. Antioxidant activity was assessed using standard analytical assays. Sensory evaluation was conducted using a trained consumer panel to evaluate taste, texture, appearance, and overall acceptability of the fortified fruit bars.

Results
The fruit bars fortified with apple and pomegranate peel powders exhibited significantly higher antioxidant activity compared to conventional fruit bars. Phytochemical analysis confirmed elevated levels of phenolic and flavonoid compounds, which are responsible for the enhanced antioxidant properties. Sensory evaluation results indicated that the fortified fruit bars maintained acceptable taste and texture, demonstrating favorable consumer acceptance despite the inclusion of peel-derived ingredients.

Conclusion & Recommendations
The findings demonstrate that apple and pomegranate peels can be effectively repurposed into value-added, antioxidant-rich fruit bars. This approach promotes sustainable food practices by reducing waste while delivering nutritionally enhanced snack products with potential health benefits. Further research may focus on shelf-life evaluation and optimization of peel incorporation levels.

Keywords: Antioxidant-rich bar; Functional foods; Phytochemical composition; Nutritional analysis

Understanding Feeding Practices and Promoting Sustainable Poultry Nutrition

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Introduction

In Pakistan, sustainable poultry production plays a vital role in ensuring food security and supporting rural livelihoods. However, rising feed costs and heavy dependence on imported soybean meal and fishmeal have increased pressure on smallholder poultry farmers. These challenges have intensified interest in alternative, locally available protein sources. Mealworms (*Tenebrio molitor*) contain 47–52% crude protein, essential amino acids, beneficial lipids, and important minerals, making them nutritionally comparable to conventional feed ingredients. Under optimized conditions, their protein content can reach up to 59–60%. Mealworms are considered a climate-smart protein source due to their low land, water, and energy requirements, as well as reduced greenhouse gas emissions. Despite these advantages, adoption among smallholder farmers in Pakistan remains limited because of low awareness and lack of local evidence.

Objectives

The study aimed to determine farmers' awareness and intentions regarding protein-enriched free-range chicken feed. It also sought to assess existing poultry feeding practices and preferences, utilize findings to initiate a pilot-scale production of mealworm-based feed at NAAC, and promote community awareness of sustainable and environmentally friendly poultry feeding practices.

Methodology

A quantitative survey approach was employed to measure awareness, perceptions, and feeding habits related to mealworm-based poultry feed among household poultry farmers in Mianwali and surrounding areas. Data were collected using a structured questionnaire, piloted with 70–90 farmers to ensure clarity and relevance. Responses were analyzed using SPSS through descriptive statistics to identify trends in awareness and adoption intentions. Ethical protocols, including voluntary participation, informed consent, confidentiality, and secure data handling, were strictly followed.

Results

Baseline awareness of insect-based feed was low; however, farmers showed strong interest in high-protein nutrition to improve poultry growth. After learning about mealworms' high protein content, balanced amino acids, and positive effects on feed efficiency, immunity, and growth, willingness to adopt increased significantly. Environmental benefits, including reduced resource use and waste recycling, further enhanced acceptance. Key barriers included cost concerns, odor, texture, and market availability. Adoption intention emerged as a strong predictor of future use.

Conclusion & Recommendations

Mealworm-based poultry feed shows strong potential as a climate-smart nutrition strategy. Awareness campaigns, farmer training, and pilot production at NAAC are recommended to support adoption and reduce reliance on imported feed sources.

Keywords: Mealworm feed, Farmer awareness, Adoption, Free-range chicken, Climate-smart agriculture

Taurine Mediated Enhancement of Mineral Bioavailability and Growth Performance in Mori Fingerlings

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Introduction
In plant-based diets, taurine, a vital component, becomes limited. The performance, health, and resistance status of aquatic life might be enhanced by using organic acids and their salts as acidifiers. Compared to organisms with warm blood, fishes have lower levels of acidic secretions in their guts. Natural acid addition to their diet lowers the pH in the stomach, enhances phytate hydrolysis, slows down the rate of gastric exhaustion, and promotes mineralization and supplement absorption.

Objectives
The purpose of this study was to assess how Mori (Cirrihinus mrigala) fingerlings' growth performance and mineral bioavailability were affected by the addition of taurine to their diet, which was based on linseed meal.

Methodology
For 60 days, Cirrihinus mrigala fingerlings were administered dietary taurine at varying graded levels (0, 1,2,3and 4 gkg-l). Fish fingerlings in triplicate groups (32 g average starting body weight) were fed the diets twice a day until they appeared satiated, and their feces were collected.

Results
Up to the ideal level of 4gkg-', dietary taurine considerably ($P<0.05$) increased fish performance; however, after that, a discernible decrease in fish development was noted because of the poor retention of several vital nutrients and minerals. At this ideal level of dietary taurine inclusion in a diet based on sunflower meals, the highest digestibility values of crude proteins (73%), crude fat (66%), and gross energy (72%), were noted. Similarly, fish fed at 4gkg taurine level had improved absorption ($P<0.05$) of most minerals (Ca, Cu, Na, P, and K).

Conclusion & Recommendations
Fish fed, a diet supplemented with 4 g/kg of taurine had the highest survival rate (98%). To improve the development and health of Mori at the 4 kg level on a diet based on sunflower meals, taurine appears to be a viable feed supplement.

Keywords: TAURINE, Minerals, growth, Cirrihinus mrigala, linseed meal

Role of Probiotics in the Control of Colibacillosis in Birds with Histopathological and Hematobiochemical Evaluation

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Introduction

Colibacillosis, caused by avian pathogenic *Escherichia coli* (APEC), is one of the most economically significant bacterial diseases affecting the poultry industry worldwide. The disease is associated with high morbidity, mortality, reduced growth performance, and severe damage to vital organs, leading to substantial economic losses. With increasing global restrictions on the use of antibiotics due to concerns over antimicrobial resistance and food safety, there is a growing need to identify safe, sustainable, and effective alternatives. Probiotics have emerged as promising biological agents capable of enhancing gut health, immunity, and disease resistance in poultry.

Objectives

This study aims to evaluate the role of probiotics in controlling colibacillosis in birds, with particular emphasis on associated histopathological alterations and changes in hematological and serum biochemical parameters following experimental *E. coli* infection.

Methodology

Birds will be randomly allocated into four experimental groups: a negative control group, an *E. coli*–challenged positive control group, an *E. coli*–challenged probiotic-treated group, and a probiotic-only group. Following experimental infection and probiotic supplementation, blood samples will be collected to assess hematological indices and serum biochemical markers. Tissue samples from the liver, kidneys, and intestines will be harvested postmortem and subjected to detailed histopathological examination to evaluate the extent of tissue damage, inflammatory response, and recovery associated with probiotic treatment.

Results

Birds challenged with *E. coli* are expected to exhibit significant hematological disturbances, including anemia and leukocytosis with heterophilia, along with elevated liver enzyme activities and increased serum creatinine and uric acid levels. Histopathological findings are anticipated to include hepatic degeneration, renal tubular damage, and intestinal villus atrophy with inflammatory infiltration. In contrast, probiotic-treated birds are expected to show marked improvement in hematological and biochemical parameters, reduced hepatic and renal lesions, and restoration of normal intestinal architecture, indicating enhanced tissue integrity and immune modulation.

Conclusion & Recommendations

Probiotic supplementation is expected to effectively mitigate pathological, hematological, and biochemical alterations associated with avian colibacillosis. These findings support the potential use of probiotics as a viable alternative to antibiotics for disease control in poultry. It is recommended that probiotics be incorporated into poultry health management programs and further evaluated under field conditions to validate their efficacy and optimize application strategies.

Keywords: Colibacillosis, probiotics, poultry, histopathology, hematology, serum biochemistry

Farmer Livelihoods in the Thal Desert of Pakistan: An Economic Review Using the Sustainable Livelihoods Framework

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Introduction

The Thal Desert of Pakistan is characterized by arid to semi-arid climatic conditions, low and erratic rainfall, fragile soils, and chronic water scarcity, all of which impose severe constraints on agricultural production and rural livelihoods. Farming communities in the region operate under high levels of environmental and economic risk, making livelihood sustainability a persistent challenge. Understanding the structure, composition, and dynamics of livelihoods in such resource-constrained environments is critical for designing effective rural development interventions and policies that enhance income stability, resilience, and long-term economic viability.

2. Objectives:

This study aims to provide an economic review of existing literature on farmer livelihoods in the Thal Desert using the Sustainable Livelihoods Framework, with the objective of assessing how different livelihood assets influence income generation, diversification strategies, and economic resilience.

Methodology

A structured literature review was conducted using peer-reviewed journal articles, government publications, and relevant policy documents focusing on livelihoods in arid and desert regions of Pakistan. The analysis systematically applied the Sustainable Livelihoods Framework to examine the roles of human, natural, physical, financial, and social capital in shaping livelihood strategies and outcomes in the Thal Desert. Studies were assessed for their economic insights into income sources, vulnerability, adaptive capacity, and institutional support mechanisms affecting farming households.

Results

The reviewed literature indicates that agriculture and livestock-based activities remain the dominant livelihood sources in the Thal Desert, with household incomes strongly influenced by land quality, rainfall variability, water availability, and access to inputs and markets. Livestock rearing consistently emerges as a critical livelihood asset, providing income diversification and serving as a buffer against crop failure. Engagement in non-farm activities, including wage labor and small enterprises, also contributes to reducing income variability and vulnerability. However, persistent constraints such as limited access to financial capital, weak market integration, environmental degradation, and inadequate institutional and extension support continue to restrict productivity growth and sustainable livelihood improvement across the region.

Conclusion & Recommendations

The review highlights significant gaps in empirical evidence related to income stability, productivity enhancement, and the effectiveness of policy interventions in arid agro-ecosystems. By synthesizing fragmented research, this study provides economically grounded insights to inform the design of inclusive and context-specific rural development strategies. Strengthening access to productive assets, improving market linkages, and enhancing institutional support are essential for promoting resilient and sustainable livelihoods in desert agricultural regions of Pakistan.

Keywords: Sustainable Livelihoods Framework; Farmer livelihoods; Thal Desert; Rural economy; Livelihood diversification; Arid agriculture

Fog Fever as a Hidden Threat to Food Security and Livelihoods in Grazing Based Livestock Systems

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Introduction
Livestock is central to food security and rural livelihoods in grazing-based production systems, providing income, animal-source foods, and asset security. However, acute nutritional and metabolic disorders in cattle remain under-recognized within food security and climate resilience frameworks. Fog fever, or Acute Bovine Pulmonary Edema and Emphysema, is an often-fatal respiratory condition in adult cattle triggered by abrupt dietary transitions from dry feed to lush pasture.

Objectives
This study examines fog fever as a livestock health challenge with direct implications for food security, household income, and livelihood resilience in grazing-based systems, particularly under conditions of increasing climate variability.

Methodology
A narrative synthesis of veterinary, nutritional, and livestock production literature was conducted to assess the etiology, clinical outcomes, economic impacts, and preventive management strategies associated with fog fever. Emphasis was placed on linking animal health outcomes with food security and climate-related pasture dynamics.

Results
Fog fever typically occurs within 5–14 days of sudden exposure to lush, high-protein pastures, resulting from ruminal conversion of dietary tryptophan into the toxic metabolite 3-methylindole. Mortality rates may reach up to 30% in affected herds, causing substantial economic losses, reduced milk production, and immediate declines in meat availability. Adult animals, the primary contributors to farm income and reproduction, are disproportionately affected, undermining both short-term food access and long-term herd productivity. Climate variability intensifies risk by promoting rapid pasture growth following dry periods.

Conclusion & Recommendations
Fog fever represents not only a veterinary concern but also a significant food security and livelihood risk in grazing-based livestock systems. Effective preventive measures such as gradual pasture introduction, provision of dry forage, and strategic use of ionophores can substantially reduce mortality and stabilize livestock-derived income. Integrating livestock health management into food security and climate adaptation strategies is essential for enhancing the resilience of rural livelihoods in climate-vulnerable regions.

Keywords: Fog fever; Livestock health; Food security; Rural livelihoods; Grazing systems; Climate variability; Rumen metabolism

Flesh Quality in Relation to Food Security

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Introduction

Fish is widely recognized for its high nutritional value, offering essential amino acids, high-quality vitamins, and beneficial fatty acids with known health advantages such as anti-thrombotic effects. In many developing countries, fish plays a crucial role in dietary protein intake, with approximately 60% of the population obtaining more than 30% of their animal protein from fish. In contrast, less than 20% of the population in most developed countries relies on fish as a primary animal protein source. However, demand is rising globally due to increased awareness of fish's health benefits and concerns related to other animal protein sources.

Objectives

This study aims to highlight the importance of fish availability and safety in developing countries and examine the challenges associated with post-harvest handling, fish quality, and the burden of fish-borne illnesses. It seeks to underscore how poor handling practices and inadequate processing undermine the nutritional and public health benefits of fish.

Methodology

The study is based on a synthesis of global reports and epidemiological data related to fish consumption, post-harvest practices, and food-borne disease statistics. Comparative analysis between developing and industrial countries was used to examine fish dependency patterns and associated health risks.

Results

Findings indicate that while fish has the potential to significantly enhance nutrition in developing countries, its safety and quality are often compromised due to unhygienic handling, inadequate refrigeration, and sub-standard processing. These conditions contribute to widespread fish-borne illnesses. In developing countries, food- and water-borne infectious diseases account for an estimated 2.1 million deaths annually, predominantly among infants and children. In industrialized nations, microbiological food-borne illnesses affect up to 30% of the population, with approximately 20 deaths per million inhabitants each year. Unwholesome fish and fishery products are responsible for up to 30% of these illnesses.

Conclusion & Recommendations

Despite its high nutritional value and importance as a protein source, fish can pose significant public health risks if not handled and processed properly. Ensuring safe post-harvest practices, improving hygiene standards, and enhancing refrigeration and processing systems are essential to safeguard fish quality and maximize its contribution to food security and public health, especially in developing countries.

Keywords: Food Safety; Fish Quality; Hygiene; Public Health

Determination of Food Safety Awareness Levels Among University Students: The Case of Tekirdağ Namık Kemal University

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Introduction

Food safety has become a major public health concern due to changing consumption patterns and the increasing complexity of industrial food production. Ensuring safe food consumption requires not only effective control mechanisms but also informed and aware consumers. University students represent a particularly important group, as their current knowledge and attitudes are likely to influence future consumption behaviors. Understanding their level of food safety awareness is therefore essential for developing effective educational and policy interventions aimed at improving public health outcomes.

Objectives

This study aims to evaluate the levels of knowledge, attitudes, and awareness related to food safety among university students and to identify key factors influencing their food safety perceptions and behaviours.

Methodology

The study was conducted at Tekirdağ Namık Kemal University using data collected from 269 students selected through random sampling. Data were obtained via face-to-face questionnaires. Descriptive statistics were employed to summarize the data, while Chi-square analysis was used to examine relationships between variables. Factor analysis was applied to identify the main sources of food safety among students.

Results

The results revealed that 81% of the students perceived their knowledge of food safety as insufficient. Regarding food label reading habits, most students (84%) reported checking expiration dates, whereas attention to product ingredients and nutritional information remained relatively low. Statistical analyses showed no significant differences in food safety knowledge levels based on gender or income level ($p > 0.05$). Factor analysis indicated that digital media platforms constitute the primary source of food safety information for students, surpassing traditional sources such as formal education and official institutions. These findings highlight notable gaps in students' understanding of food safety practices, particularly concerning certification systems and inspection processes.

Conclusion & Recommendations:

The study concludes that food safety awareness among university students is inadequate and requires improvement. Limited knowledge of official food safety controls and certifications poses a potential risk to informed consumption. It is recommended that food safety and food literacy education be integrated into university curricula, supported by campus-based awareness programs and digital media initiatives. Promoting access to reliable and authoritative information sources may contribute to improving students' food safety awareness and long-term consumer behavior.

Keywords: Food safety, consumer awareness, university students, label reading, consumer behavior

Food Security and Women's Livelihoods in Developing Economies: Challenges, Policies, and Sustainability Pathways

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Introduction
Socio-economic development is dependent on food security and the livelihoods of women, especially in developing countries, where women are the primary players in the agricultural sector, food production, and household nutrition. Women have suffered the most due to climate change, resource shortage, and financial instability, which have predisposed them to food insecurity and livelihood shocks. The reinforcement of women-based food systems by sustainable farming, livelihood diversification, and inclusive policy frameworks is also being seen as one of the main approaches towards improving resilience, alleviating poverty, and granting long-term food security.

Objectives
The objectives of this study are to: comprehend the challenge of women in the assurance of food security and sustainable livelihoods; examine the impact of women's participation in the agricultural and income-yielding and resource access on the food security outcomes; and assess the gender sensitive policy options that can help to enhance resilient livelihoods of women in rural and farming economies

Methodology
Primary data were collected through a household survey in Faisalabad. Household consumption was assessed across key dimensions, including food intake, transportation, income, housing size, and electricity usage. Ecological footprints were estimated using an online ecological footprint calculator. Empirical analysis employed descriptive statistics, correlation analysis, multiple linear regression, chi-square tests, and Eta tests to identify the major determinants of household ecological footprints.

Results
The review suggests that the accessibility of women to productive resources, agricultural inputs, and opportunities enroute to livelihood diversification are important determinants of household food security. The participation of women in sustainable and income-earning agricultural activities renders to climatic and economic shocks, an improvement in livelihood stability and sustainability. The positive results of food security are further enhanced by institutional support, financial inclusion, and market access, which point to the efficacy of integrated and women-based interventions.

Conclusion & Recommendations
Food security and the livelihoods of women have a strong relationship and need to be negotiated through gender responsive development policies. These policies guiding the empowerment of women, fair sharing of resources, and processes of agricultural adaptation to climate are the key elements of decreasing the level of vulnerability and increasing the ability to face the outcome of the climate. A key strategy for ensuring food security and sustainable livelihoods involves dedicated investment in strengthening women's capabilities, developing rural infrastructure, and promoting inclusive institutions. Localized and gender-disaggregated evidence on effective intervention policies and development should focus on future research.

Keywords: Women and Food Security; Women livelihoods; Gender equality in agriculture; climate resilience; rural development; poverty reduction; institutional support; equitable growth

Assessment of Wheat Germplasm Using Multivariate Analysis for Grain Yield and Quality Traits in Spring Wheat

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Introduction

Genetic diversity is a key prerequisite for the development of high-yielding and quality-improved wheat cultivars. This study was conducted to assess genetic diversity among fourteen spring wheat (Triticum aestivum L.) genotypes using multivariate statistical techniques. Phenotypic evaluation of yield-related traits and laboratory-based assessment of grain physical and nutritional quality parameters were carried out to identify diverse parental lines suitable for wheat breeding programs. Multivariate analyses, including Principal Component Analysis (PCA) and cluster analysis, were applied to elucidate patterns of variation and genetic divergence among the genotypes.

Objectives

The objective of this study was to evaluate genetic diversity among wheat genotypes for grain yield and quality traits and to identify genetically diverse parental lines that can broaden the genetic base of wheat breeding programs and contribute novel alleles for yield and quality improvement.

Methodology

Field experiments were conducted to record seven quantitative traits: plant height, number of spikes per plant, spike length, number of spikelets per spike, number of grains per spike, spike biomass, and grain yield per plot. Grain quality analyses were performed at the Cereals Laboratory, Ayub Agricultural Research Institute, Faisalabad. Physical grain traits, including thousand-kernel weight and Single Kernel Characterization System (SKCS) parameters, were measured. Nutritional quality traits such as protein, starch, gluten content, Zeleny sedimentation rate, ash, crude fat, and fiber were analyzed using standard laboratory procedures.

Results

PCA revealed that the first seven principal components accounted for over 88% of the total genetic variation. The first principal component was mainly associated with gluten content, protein content, grain weight, and grain diameter, while the second component was influenced by starch, fat, and fiber. Cluster analysis based on PCA grouped the genotypes into four distinct clusters, indicating substantial genetic divergence.

Conclusion and Recommendations

The genotypes 88146, Fareed-06, 6317, and 88132 were identified as the most genetically diverse and are recommended as potential parents for crossing programs. Utilizing diverse parents from different clusters can enhance heterosis, broaden genetic diversity, and improve grain yield and quality traits in wheat breeding programs in Pakistan.

Keywords: Wheat, Grain Quality Traits, Nutritional Profile

Association Mapping of Economic Traits Using QTL Clusters and Hotspots Linked SSR Markers in Upland Cotton

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Introduction

Association mapping has been widely applied in cotton to dissect the genetic basis of agronomic, yield, and fiber quality traits using diverse molecular markers. However, limited attention has been given to the use of simple sequence repeat (SSR) markers derived from quantitative trait loci (QTL) clusters and hot spots identified through meta-QTL analysis. Exploiting such genomic regions may enhance the detection of stable and pleiotropic loci controlling economically important traits. This study addresses this gap by focusing on SSR markers linked to QTL clusters and hotspots in upland cotton (*Gossypium hirsutum* L.).

Objectives

The objectives of this study were to: (i) assess the genetic diversity of SSR markers derived from QTL clusters and hotspots; (ii) identify SSR loci associated with key economic traits through association mapping; and (iii) integrate linkage and association mapping approaches to evaluate their effectiveness for dissecting complex traits in cotton.

Methodology

A diverse natural population comprising 503 upland cotton accessions developed between 1920 and 2011 was evaluated across two years and eight environments. A total of 298 SSR markers located in the vicinity of reported QTL clusters and hotspots were screened, of which 81 polymorphic markers were used for genetic diversity, linkage disequilibrium (LD), and association analyses. Association mapping for 16 economic traits was performed using a General Linear Model (GLM-Q) to control population structure.

Results

The analysis identified 56 significant marker–trait associations involving 14 economic traits. Approximately 15 SSR markers exhibited pleiotropic effects, being associated with two or more traits. Meta-QTL analysis revealed 48 QTL clusters distributed across 17 chromosomes, including six QTL hotspots and 22 meta-QTLs linked to yield, growth, and fiber quality traits. Only 11.88% of the SSR markers showed significant LD ($P \leq 0.01$), indicating adequate resolution for association mapping.

Conclusion and Recommendations

The identified SSR markers associated with economic traits provide valuable resources for marker-assisted selection and QTL fine mapping. Integrating association mapping with meta-QTL analysis enhances the understanding of complex trait architecture and supports the development of improved cotton cultivars.

Keywords: SSRs, QTL Clusters, QTL Hotspots, Meta-QTL

Impact of Sustainable Smart Agriculture on Rural Development and Food Security

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Introduction

Sustainable smart agriculture integrates digital innovation with climate-smart practices to address growing challenges related to crop productivity, food quality, farmer profitability, and rural development. Rapid climate change, water scarcity, soil degradation, and rising production costs increasingly threaten agricultural livelihoods and global food systems. Traditional farming methods alone are insufficient to cope with these pressures, creating an urgent need for adaptive, data-driven, and resource-efficient solutions. Smart agriculture leverages technologies such as artificial intelligence, renewable energy, and advanced analytics to enhance decision-making, optimize inputs, and reduce environmental impacts while strengthening the resilience of farming systems.

Objectives

This study aims to explore emerging smart agricultural technologies and assess the impacts of artificial intelligence (AI), renewable energy–based irrigation systems, and climate-smart analytics on crop productivity, income stability, resource-use efficiency, and environmental sustainability.

Methodology

The study adopted a mixed-method approach combining an extensive review of peer-reviewed literature with field-based observations and comparative analysis. Smart agricultural interventions were assessed by examining AI-driven decision-support systems for irrigation scheduling, fertilizer application, and pest management. Renewable and non-renewable irrigation practices were compared to evaluating water-use efficiency and energy consumption. Additional analysis focused on the role of nanoparticles in nutrient delivery and the performance of decoupled recirculating aquaponics systems (DRAPS) in improving soil health, crop productivity, and integrated food production efficiency.

Results

The findings demonstrate that smart irrigation systems and data-driven cultivation practices significantly enhance crop yields while reducing water use, chemical inputs, and environmental pollution. AI-enabled tools improved fertilizer efficiency, pest detection, soil health monitoring, and market-oriented decision-making, resulting in higher productivity and cost savings. Renewable energy–based irrigation reduced dependence on fossil fuels and stabilized farm operating costs. Climate-resilient technologies enhanced farmers' adaptive capacity to temperature variability and water stress. Nanoparticle applications improved nutrient uptake efficiency and crop nutritional quality, while DRAPS supported integrated, resource-efficient production systems with minimal waste generation.

Conclusion & Recommendations

The integration of AI, renewable energy, and climate-smart technologies with conventional agricultural practices strengthens system resilience, optimizes resource use, and supports long-term food security. Policymakers should promote community-cantered smart agriculture through targeted investments, infrastructure development, farmer training, and supportive regulatory frameworks. Scaling up these innovations can enhance sustainable rural livelihoods while mitigating climate risks.

Keywords: Smart agriculture, climate change, artificial intelligence, DRAPS, nanoparticles.

Pathways to Climate-Smart Agriculture Adoption for Food Security and Resilience: Roles of Skill Enhancement and Institutional Capacity in Livelihood Improvement toward the Sustainable Development Goals

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Introduction
Climate change, resource depletion, and intensified conventional farming threaten global food security and rural livelihoods. Unsustainable practices accelerate soil degradation, water scarcity, biodiversity loss, and greenhouse gas emissions, heightening vulnerability to climate shocks. Climate-Smart Agriculture (CSA) offers an integrated framework to enhance productivity, strengthen adaptation, and reduce environmental impacts. However, large-scale CSA adoption requires more than technology; it depends on skilled human capital, continuous training, effective extension services, and strong institutional support systems globally sustainable.

Objectives

This review aims to (i) analyze the role of skill development and capacity building in enabling CSA adoption, (ii) assess the economic and livelihood outcomes associated with CSA practices, and (iii) identify policy and institutional frameworks necessary for scaling sustainable and climate-resilient agriculture.

Methodology

A systematic narrative review was conducted using peer-reviewed journal articles, international reports, and policy documents from organizations such as FAO, World Bank, ADB, IFA, IOFS, and relevant national agencies. Literature on CSA, climate-resilient agriculture, sustainable land and water management, organic farming, and precision agriculture were critically analyzed. Comparative insights were drawn from South Asia, particularly Pakistan, the CAREC region, Sub-Saharan Africa, and other climate-vulnerable regions. Thematic analysis was employed to link CSA adoption with skill development, institutional capacity, and livelihood outcomes.

Results

The reviewed evidence shows that CSA practices, including conservation agriculture, organic farming, precision irrigation, climate-resilient crops, agroforestry, and digital agriculture, enhance productivity, resource efficiency, and resilience to climate variability. Economic and livelihood benefits are strongest where adoption is supported by training, extension, and capacity. Integrated CSA approaches deliver greater food security and income gains than isolated practices. Skill development improves adaptive capacity and market participation. Adoption remains uneven due to financial constraints, weak policies, limited technology access, and inadequate training, especially for smallholders and women.

Conclusion & Recommendations

CSA represents a critical pathway for achieving food security and sustainable rural livelihoods under climate change. Scaling CSA requires a shift from technology-centric approaches toward integrated strategies emphasizing skill development, institutional strengthening, and policy coherence. Policymakers should align agricultural and climate policies, invest in extension and training systems, expand access to finance, and promote public–private partnerships. Strengthening human and institutional capacity is essential to unlock the full economic, social, and environmental benefits of climate-smart agriculture.

Keywords: Climate-Smart Agriculture; Food Security; Skill Development; Sustainable Livelihoods; Economic Growth

Role of Livelihood Interventions in Enhancing Nutritional Security

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Introduction
Livelihood interventions play a critical role in improving nutritional security by enhancing household income, food availability, and dietary diversity, particularly among vulnerable populations. Integrating livelihood-based approaches with nutrition-sensitive strategies has gained increasing attention as a sustainable pathway to address undernutrition in developing regions.

Objectives
This study explores the contribution of livelihood interventions to improved nutritional outcomes through sustainable income generation, dietary diversification, and resilience building.

Methodology
The abstract synthesizes evidence from existing literature on livelihood-based interventions, including agricultural diversification, livestock rearing, small-scale agribusiness, microfinance, and skills development. The analysis focuses on their effects on household food security, dietary diversity, and nutritional outcomes, with particular attention to women and children in developing contexts.

Results
Evidence indicates that households engaging in diversified livelihood activities demonstrate higher dietary diversity scores, increased consumption of protein- and micronutrient-rich foods, and a lower prevalence of undernutrition. Livelihood diversification reduces dependence on single income sources, thereby strengthening resilience to economic and climatic shocks. Furthermore, livelihood interventions combined with nutrition education and gender-sensitive approaches yield greater nutritional benefits by improving food choices and promoting equitable intra-household food distribution. Community-based livelihood initiatives also enhance social capital and strengthen local food systems, contributing to long-term nutritional sustainability.

Conclusion & Recommendations
Livelihood interventions have significant potential to enhance nutritional security; however, their effectiveness depends on contextual factors such as market access, resource availability, policy support, and program design. Integrated strategies that combine livelihood improvement with nutrition-sensitive programming are essential to maximize nutritional impacts. Multisectoral collaboration and evidence-based policy frameworks are therefore required to strengthen the livelihood–nutrition nexus and advance food and nutritional security, broader development goals, and overall well-being.

Keywords: Livelihood interventions; Nutritional security; Food security; Dietary diversity; Sustainable livelihoods; Income generation; Nutrition-sensitive development

Participation of Rural Females in Non-agriculture Sector of Pakistan: The Case of Faisalabad

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Introduction

In developing countries like Pakistan, the rural non-farm sector plays a vital role in generating employment opportunities, particularly for landless and resource-poor households. For rural women, participation in non-agricultural activities is especially important as it provides an alternative source of income and enhances household economic security. In the rural areas of Faisalabad, women are actively engaged in home-based enterprises such as stitching, embroidery, garment making, and jewelry production. These activities not only utilize traditional skills but also contribute to livelihood diversification. The present study focuses on three major occupations i.e. stitching, embroidery, and garment making, to assess their economic significance.

Objectives

The primary objective of this study is to examine the level of participation and economic contribution of rural women in the non-agricultural sector of Faisalabad and to assess the impact of their involvement on household income and economic welfare.

Methodology

Primary data were collected from five randomly selected villages of Faisalabad district. A total of 100 rural women engaged in non-farm activities were interviewed using a well-structured questionnaire. Information was gathered on socio-economic characteristics, work patterns, income levels, and access to training. Multiple linear regression analysis was employed to identify the key determinants of women's income from non-agricultural activities. The data were analyzed using the Statistical Package for Social Sciences (SPSS) to ensure accuracy and reliability of results.

Results

The results of the multiple linear regression analysis reveal that age, education, number of working hours, and access to vocational training have a positive and statistically significant impact on the income earned by rural women. Educated women and those who received skill-based training were able to earn higher incomes due to better productivity and access to markets. Longer working hours also contributed positively to income generation. In contrast, family size and husband's income were found to have a negative relationship with women's earnings, suggesting that higher household responsibilities and greater reliance on spousal income reduce women's economic participation and motivation. Overall, the findings highlight the importance of human capital development and skill enhancement in improving women's earnings in the rural non-farm sector.

Conclusion & Recommendations

The study concludes that rural women can contribute more effectively to household welfare through non-agricultural employment if enabling conditions are provided. The establishment of vocational training institutes, improved access to skill development programs, and provision of childcare facilities in rural areas are strongly recommended. Such interventions can enhance women's productivity, increase incomes, and promote inclusive rural economic development.

Keywords: Rural areas, non-agriculture sector, employment, education, income

Hedonic Price Model for Assessing the Impact of Industrial Pollution on Housing Values in Punjab Pakistan

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Introduction

Housing is a fundamental human need, and its value is strongly influenced by environmental quality and locational characteristics that shape overall living conditions. In rapidly urbanizing and industrializing regions of developing countries, residential areas are increasingly exposed to industrial pollution, hazardous waste sites, and environmental degradation. These environmental disamenities generate negative externalities that reduce property values and influence household residential choices. In Pakistan, particularly in Punjab province, rapid industrial expansion combined with weak land-use planning has resulted in the proximity of industrial zones and residential neighborhoods. Major cities such as Lahore and Faisalabad face severe air, water, land, and noise pollution generated by industrial activities. Despite growing public concern, empirical evidence on how hazardous industrial waste sites affect housing values in Pakistan remains limited. This study addresses this gap by applying the Hedonic Price Model to examine the effect of environmental disamenities and housing attributes on residential property values in Punjab.

Objectives

The primary objective of this study is to evaluate the impact of proximity to hazardous industrial waste sites on housing values in Punjab, Pakistan. Specifically, the study aims to estimate the contribution of structural, neighborhood, and locational characteristics to housing prices, quantify the effect of distance from industrial sites on residential property values, and assess the role of environmental quality in shaping households' willingness to pay for improved living environments.

Methodology

The study employs a semi-log Hedonic Price Model using primary data collected from 400 households in Lahore and Faisalabad. A stratified random sampling technique ensured representation across industrial and non-industrial zones. Housing value per square meter is used as the dependent variable. Independent variables include housing floor area, housing age, household income, access to schools and workplaces, distance from main markets, distance from industrial sites, and an environmental quality index capturing air, water, and land conditions. Regression techniques were applied to estimate marginal effects.

Results

The empirical results indicate that the model explains approximately 63 percent of the variation in housing values. Housing size has a positive and statistically significant effect, while housing age negatively affects property prices. Proximity to industrial sites significantly reduces housing values, whereas improved environmental quality increases them.

Conclusion & Recommendations

The findings confirm that hazardous industrial activities impose negative externalities on nearby residential properties and highlight the need for environmentally informed urban planning and stronger industrial zoning policies.

Keywords: Hedonic Price Model; Housing Value; Industrial Pollution; Hazardous Waste Sites; Environmental Quality; Urban Housing Markets; Punjab, Pakistan

Invitro Propagation and Acclimatization of Kinnow Mandarin (Citrus Reticulata Blanco) Under Hot Arid Climatic Conditions

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Introduction

The Citrus genus is widely distributed across tropical and subtropical regions including Pakistan, India, southern China, New Caledonia, and northern Australia. Kinnow mandarin (Citrus reticulata Blanco) is an economically important citrus variety, yet its propagation is limited by environmental stresses and low regeneration efficiency. This study focuses on optimizing direct shoot regeneration from internodal stem segments and successful acclimatization of plantlets under hot arid climatic conditions.

Objectives

The objectives of this study were to: evaluate various MT-based media formulations containing malt extract, sucrose, and growth regulators for efficient shoot regeneration; identify optimal hormonal combinations for enhanced shoot length, root induction, and root elongation; and acclimatize regenerated Kinnow mandarin plantlets under arid, high-temperature environmental conditions.

Methodology

Internodal stem segments of Kinnow mandarin were cultured on MT medium supplemented with 0.5 mg/L malt extract and 50 g/L sucrose. A total of 36 media formulations containing different concentrations of BAP, kinetin, IBA, NAA, and activated charcoal were tested. Shoot regeneration, shoot length, root length, and number of roots were analysed at a 0.05 significance level. Selected plantlets were subjected to heat shock under in-vitro conditions before acclimatization in arid outdoor environments.

Results

MT1 medium containing 0.5 mg/L BAP produced the highest mean number of shoots, showing slight but significant improvement compared to other formulations. MT45 containing 3 mg/L BAP + 1.5 mg/L kinetin resulted in the highest mean shoot length, though the difference was non-significant. Root elongation was greatest on MTR4 medium containing 0.4 mg/L IBA + 0.1 mg/L NAA + 0.5 mg/L activated charcoal, while the highest and highly significant number of roots was observed on MTR10 with 1 mg/L IBA + 0.1 mg/L NAA + 0.5 mg/L activated charcoal. Heat-shock treatment and subsequent acclimatization were successful under hot arid conditions.

Conclusion & Recommendations

This study demonstrates that optimized MT-based media with specific hormonal combinations can significantly enhance the micropropagation efficiency of Kinnow mandarin. MT1 is recommended for shoot regeneration, MT45 for shoot elongation, and MTR10 for robust root development. Acclimatization under arid conditions was effective, indicating the protocol's suitability for citrus propagation in heat-stressed regions. Future work should explore long-term field performance and genetic stability of micro propagated plants.

Keywords: Micropropagation, Shooting, Rooting, Acclimatization, Direct regeneration, Hot arid climate

Exploring Banana Peel as a Source of Natural Antibacterial Agents and Phytochemicals

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Introduction

Banana (*Musa sapientum*) is one of the most widely cultivated tropical fruits and is rich in essential nutrients and bioactive compounds. Banana peels, often discarded as waste, contain significant amounts of phytochemicals such as flavonoids, phenols, tannins, saponins, and alkaloids, which are known for their antibacterial and antioxidant properties. Although synthetic antibiotics are commonly used to treat bacterial infections, the rapid emergence of antimicrobial resistance poses a serious global health threat. Exploring plant-based alternatives has therefore become increasingly important. The antimicrobial evaluation of dried banana peel extracts provides valuable insight into their potential to inhibit bacterial growth and offers a sustainable, natural alternative to conventional antimicrobial agents.

Objectives

This study aims to evaluate the antibacterial activity of banana peel extracts through preliminary phytochemical screening and in vitro assessment against selected food spoilage and pathogenic bacteria.

Methodology

Banana peels were collected, dried, and processed into powder before extraction. Three types of extracts were prepared using ethanol and methanol as organic solvents and distilled water for aqueous extraction. Phytochemical screening was conducted using standard qualitative tests to identify the presence of major bioactive compounds. The antibacterial activity of each extract was evaluated in vitro against selected food spoilage organisms, including *Streptococcus*, *Bacillus*, *Escherichia coli*, and *Pseudomonas*, using the agar well diffusion method. Zones of inhibition were measured to assess antibacterial effectiveness.

Results

Among the three extracts tested, the ethanol extract exhibited the highest antibacterial activity, producing a maximum zone of inhibition of 30 mm against the selected bacterial strains. This enhanced activity is attributed to the higher solubility of key phytochemicals in ethanol, resulting in greater extraction efficiency. Methanolic extracts showed moderate antibacterial effects, while aqueous extracts demonstrated comparatively lower activity. The presence of phenols, flavonoids, tannins, and alkaloids was positively correlated with antibacterial performance, confirming their role in inhibiting microbial growth.

Conclusion & Recommendations

The study demonstrates that banana peel, a commonly discarded agricultural by-product, is a valuable source of natural antimicrobial compounds. Ethanol extracts showed strong antibacterial activity against both Gram-positive and Gram-negative bacteria. These findings suggest that banana peel extracts may be effectively utilized in food preservation, pharmaceutical formulations, cosmetics, and bio-based agricultural inputs. Further research is recommended to isolate active compounds and evaluate their safety and efficacy in practical applications.

Keywords: Banana peel, tannins, alkaloids, saponins, phenols

Development and Physiochemical Evaluation of Legume Enriched Cake Pops as a Functional Food for Osteoporosis Management

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Introduction

Osteoporosis is a major public health concern characterized by reduced bone mineral density and an increased risk of fractures, particularly among postmenopausal women and the elderly. Long-term deficiencies of protein, calcium, magnesium, and other micronutrients essential for bone health significantly contribute to its development. Dietary strategies based on functional foods provide a safe and sustainable approach to osteoporosis management.

Objectives

The study aimed to develop and evaluate legume-enriched cake pops as a functional food product for osteoporosis management by incorporating chickpea flour and moong dal flour with whole wheat flour and assessing their physicochemical and nutritional properties relevant to bone health.

Methodology

An experimental food product development approach was adopted. Chickpea and moong dal were cleaned, processed, and milled into flour, which were used to partially replace whole wheat flour in different formulations along with brown sugar and milk. Cake batter was prepared using standardized mixing and baking procedures, followed by cooling, shaping into cake pops, and mounting on sticks. Physicochemical and nutritional analyses, including moisture, ash, protein, fat, carbohydrate, and energy content, were conducted using standard analytical methods.

Results

Legume-enriched cake pops demonstrated improved nutritional quality, particularly in protein and mineral content, while maintaining acceptable physical characteristics. Among the formulations tested, one showed superior nutritional attributes relevant to bone health without compromising product quality.

Conclusion & Recommendations

The findings indicate that legume-enriched cake pops have potential as a convenient and acceptable functional food to support bone health and contribute to the dietary prevention and management of osteoporosis.

Keywords: Osteoporosis, Functional food, Legume-enriched cake pops, Chickpea flour, Moong dal flour, Bone health, Physicochemical evaluation, Nutritional intervention

Creating a Health-Boosting Probiotic Chocolate Spread Using an Innovative Approach

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Introduction

Rising consumer demand for functional foods has driven interest in products that combine health benefits with sensory appeal. Chocolate spreads are widely consumed, yet they are typically characterized by high sugar and fat contents and limited functional value. Incorporating nutrient-dense ingredients such as hazelnuts and yogurt powder provides an opportunity to enhance nutritional quality, add protein and minerals, and introduce probiotic functionality. Hazelnuts contribute healthy fats and micronutrients, while yogurt powder serves as a carrier of beneficial lactic acid bacteria that support digestive health. Developing a probiotic chocolate spread aligns with preferences for convenient and health-oriented food products.

Objectives

This study aimed to develop a nutritious, probiotic-rich chocolate spread formulated with hazelnuts and yogurt powder. The objectives were to evaluate nutritional composition, physicochemical properties, probiotic viability, and sensory acceptability, and to assess its potential as a functional alternative to conventional chocolate spreads.

Methodology

A chocolate spread formulation was developed by incorporating roasted hazelnuts, yogurt powder, cocoa ingredients, and *Lactobacillus plantarum* as probiotic culture. The product was analyzed for proximate composition, including moisture, ash, fat, and protein content. Physicochemical characteristics such as viscosity and stability were measured. Microbial analysis determined probiotic survival, while sensory evaluation using consumer panels assessed taste, texture, aroma, and overall acceptability.

Results

The probiotic chocolate spread exhibited a moisture content of 12.87% ± 0.02 and ash content of 0.73% ± 0.15, indicating formulation stability and consistent mineral presence. Fat content remained balanced at 34.53% ± 0.25, while protein content increased to 7.42% ± 0.11 due to hazelnuts and dairy components. The viscosity value of 350.63 ± 0.25 confirmed a smooth, spreadable texture. Microbiological analysis showed a viable probiotic count of 111.00 ± 3.61 CFU/g. Sensory scores reflected consumer acceptance.

Conclusion & Recommendations

The study demonstrates that hazelnut- and yogurt powder–enriched probiotic chocolate spread delivers improved nutrition and viable probiotics. Such products offer promise as functional foods supporting gut health.

Keywords: Probiotic, hazelnuts, chocolate spread, gut health

An Empirical Analysis of Financial Development, Energy Consumption, and Ecological Footprint in Pakistan

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Introduction

Climate change and environmental degradation pose significant challenges to sustainable development in developing economies such as Pakistan. Rapid economic growth, financial sector expansion, increased energy consumption, and trade openness have intensified environmental pressures, necessitating an integrated understanding of the growth–energy–environment nexus.

Objectives

This study investigates the short-run and long-run relationships among financial development, renewable and non-renewable energy consumption, trade openness, ecological footprint, and economic growth in Pakistan.

Methodology

Annual time-series data spanning 1990–2019 were analyzed using the Autoregressive Distributed Lag (ARDL) approach. This methodology allows for the examination of dynamic interactions and cointegration relationships among the selected variables while accommodating different orders of integration.

Expected Results

The empirical results indicate that financial development, renewable energy consumption, and trade openness significantly reduce Pakistan's ecological footprint, whereas economic growth and dependence on non-renewable energy sources increase environmental pressure. At the same time, financial development, both renewable and non-renewable energy consumption, and trade openness were found to be significant drivers of economic growth. Notably, renewable energy emerged as a critical factor capable of simultaneously supporting economic growth and improving environmental quality.

Conclusion & Recommendations

The findings underscore the importance of an integrated policy framework that strengthens the financial sector, accelerates the adoption of renewable energy, and promotes energy-efficient and environmentally sustainable technologies. Such coordinated strategies are essential for achieving long-term economic growth in Pakistan while preserving environmental integrity.

Keywords: Financial development; Renewable energy; Ecological footprint; Economic growth; Trade openness

Effect of Alternating Canal and Marginal Groundwater Irrigation on Banana Yield, Water Use Efficiency, and Soil Salinity under Furrow Plantation

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Introduction

Banana is one of the most important cash crops in Sindh, Pakistan; however, its production is increasingly compromised due to declining freshwater availability. Currently, bananas are cultivated using conventional flat basin irrigation, which results in low water use efficiency (WUE). Groundwater in the region is predominantly marginal to saline in quality but could potentially supplement limited freshwater resources. Therefore, it is essential to evaluate the conjunctive use of marginal-quality groundwater and canal water to address freshwater shortages without compromising crop yields.

Objectives

This study was conducted to answer the following questions: 1) Does growing banana on furrows with alternate irrigation using canal and marginal groundwater at different levels of available soil moisture depletion (ASMD) significantly reduce irrigation water use, while improving crop yield and water use efficiency (WUE) compared to conventional farmer practices?; 2) Can furrow planting combined with the use of marginal-quality groundwater increase banana yield?; 3) Does transplanting banana on furrows with alternate irrigation of canal and marginal groundwater affect soil salinity?

Methodology

In this study, the Dwarf Cavendish banana variety (locally known as Basrai) was cultivated over a four-year period (October 2015–June 2019) on furrows (0.90 m furrow width, 1.20 m bed width, and 0.23 m bed height). Alternate irrigation using canal and marginal groundwater was applied at three levels of available soil moisture depletion (ASMD): 50%, 40%, and 30%. Traditional farmer irrigation practices were also monitored for comparison.

Results

At ASMD levels of 50%, 40%, and 30%, annual water applications were 1228 mm, 1403 mm, and 1592 mm, respectively. In contrast, farmers applied 2866 mm of water annually. Irrigation at 50% ASMD resulted in 12–23% higher yield and 23–41% higher WUE compared to 30% and 40% ASMD treatments. Compared to the 50% ASMD treatment, farmer practices produced 24% lower yield and 67% lower WUE. Importantly, soil salinity remained within acceptable threshold limits across all treatments.

Conclusion & Recommendations

These results suggest that bananas can be successfully cultivated on furrows using alternate irrigation with canal and marginal groundwater at 50% ASMD. This strategy offers substantial water savings while improving yield and WUE, making it a viable and sustainable solution for banana production in water scarce regions.

Keywords: Banana production, soil moisture depletion, water use efficiency, furrow, water saving, Pakistan

Improving Consumers Livelihood and Food Security by Enhancing Legume Productivity by Precursor-Inoculum Synergies in Pesticide-Polluted Soil

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Introduction
Glyphosate, a systemic herbicide, is widely used in agriculture, forestry, and urban landscaping. However, its uncontrolled use has resulted in buildup across various environmental matrices, particularly in soil and aquatic ecosystems, raising growing concerns about its ecological and health impacts. Glyphosate is highly toxic to all living organisms, and its bioaccumulative nature allows it to enter the food chain. Thus, its removal from the environment and reducing its entry into consumer products is highly crucial for the safety of human and ecological health.

Objective
This study aimed to use microbes and L-tryptophan (a precursor of a growth regulator, auxin) synergies to remove glyphosate from soil and enhance overall growth of mungbean and soybean in glyphosate-polluted soil and minimize its entry into legume grains.

Methodology
In this study, three bacterial cultures (BCs) were developed and tested, along with L-tryptophan (L-TRP) as a co-substrate, for their potential to degrade glyphosate and enhance the growth of mungbean at glyphosate contamination of 368 mg kg-1 in soil in pot experiments.

Results
BCs treatment significantly increased (up to 58%) the plant growth, physiology, nutrient uptake, and soil microbial biomass nitrogen and carbon over the uninoculated control. Overall, BC3 demonstrated the best performance in promoting plant growth, followed by BC1 and BC2. Soil health indicators, physiology, growth, biochemical, and yield attributes of both legume plants (i.e., mungbean and soybean) were further enhanced when BCs were supplemented with L-TRP, thereby ensuring food security. Furthermore, the co-use of bacterial cultures and L-TRP showed the maximum removal of glyphosate from the soil among all treatments; however, this combination substantially reduced the glyphosate accumulation in plant tissues, minimizing the entry of glyphosate in the food chain.

Conclusion & Recommendations
These findings suggest that the precursor-inoculum synergy is very effective in improving sustainable and safe crop production, ensuring food security and the livelihood of consumers. Moreover, the developed novel microbial bioresource could be a promising option for treating pesticide-contaminated soil. Outcomes of this study are useful and contribute to addressing United Nations Sustainable Development Goals 2 and 3.

Keywords: Bacterial cultures, L-tryptophan, bioremediation, soil health restoration, food security

CRISPR-Mediated Genome Editing for Enhancing Heat Tolerance and Fertility in Livestock

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Introduction

Livestock productivity is increasingly threatened by heat stress resulting from intensified climate change. Elevated temperatures disrupt endocrine balance, impair gamete quality, reduce conception rates, and compromise overall reproductive efficiency. Conventional breeding and selection programs have shown limited success in mitigating heat stress, highlighting the need for innovative and targeted genetic approaches.

Objectives

This study aims to review and synthesize recent advancements in genome editing, particularly CRISPR-Cas systems, for enhancing thermotolerance and reproductive performance in livestock under heat stress conditions.

Methodology

Recent scientific literature was examined to evaluate the application of CRISPR-Cas genome editing in modifying genes associated with thermoregulation and reproduction. Key target genes related to heat tolerance (e.g., *HSP70*, *HSP90*, and the *PRLR* SLICK phenotype) and reproductive efficiency (e.g., *FSHR*, *IGF1*, and *BMP15*) were reviewed to assess their functional relevance and reported outcomes.

Results

Findings from recent studies indicate that CRISPR-Cas technology has been successfully used to edit major thermotolerance-related genes, resulting in improved heat resistance and physiological adaptability in livestock. Modifications of heat shock protein genes (*HSP70* and *HSP90*) and the *PRLR* SLICK mutation have demonstrated enhanced thermoregulation. Additionally, editing of reproduction-related genes has shown potential for improving fertility traits, gamete quality, and conception rates under heat stress conditions.

Conclusion & Recommendations

CRISPR-Cas genome editing represents a promising and precise strategy for developing heat-resilient and reproductively efficient livestock in the face of climate change. By directly targeting genes involved in thermotolerance and reproductive performance, this technology offers a faster and more effective alternative to traditional breeding methods. Future research should focus on ethical considerations, regulatory frameworks, and long-term performance evaluation to enable the safe and sustainable application of genome editing in livestock production systems.

Keywords: Fertility, Genes, Genome, heat stress, Livestock

Determinants of Low-Carbon Farming Practice Adoption in the Cotton–Wheat System of Pakistan's Indus Basin

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Introduction

Climate change, conventional agricultural management practices, and increasing water scarcity pose serious threats to agricultural productivity, biodiversity, and environmental sustainability. These challenges necessitate improved management strategies to prevent resource over-exploitation and groundwater salinity. Low-carbon farming practices, which aim to reduce greenhouse gas emissions and enhance carbon sequestration while sustaining farm productivity and resilience, represent an innovative and environmentally cleaner alternative to conventional agriculture.

Objectives:

This study aims to estimate the determinants and intensity of adoption of low-carbon farming practices of sustainable agriculture in the Indus Basin System of Pakistan, with a particular focus on the cotton–wheat cropping system of South Punjab.

Methodology:

Primary data were collected from 300 farm households across 30 villages in major cotton-growing districts of South Punjab, Pakistan. The adoption of key low-carbon farming practices including soil carbon sequestration, efficient input use, climate-smart crops and livestock management, agroforestry and tree-based systems, reduction of methane and nitrous oxide emissions, and on-farm renewable energy use was assessed. Logistic regression models were employed to analyze factors influencing the probability of adoption, and marginal effects were estimated to determine the impact of changes in explanatory variables on adoption outcomes.

Results:

The findings indicate that farmers in the cotton–wheat cropping system have adopted a range of low-carbon farming practices. The logistic regression results reveal that farm characteristics, economic and social capital, access to technical training, information sources, and exposure to climate risks significantly influence the adoption of low-carbon practices. The estimated coefficients indicate the direction of influence of explanatory variables, while marginal effects quantify their relative impacts. Model diagnostics, including pseudo-R^2 and Wald chi-square statistics, confirm that the estimated models are statistically adequate and well-fitted.

Conclusion & Recommendations

The study concludes that adoption of low-carbon farming practices in the Indus Basin is shaped by a combination of socioeconomic, institutional, and informational factors. To accelerate the transition toward sustainable and low-carbon agriculture, government and relevant institutions should implement targeted policies that promote awareness, capacity building, and financial support for farmers. Such interventions can enhance resource-use efficiency, increase farm income, and improve rural livelihoods in South Punjab and other wheat-based cropping systems.

Keywords: low carbon; south Punjab, Cotton; greenhouse gas; resilience; productivity; cleaner production

Physiological and Histopathological Impact of Green-Synthesized Silver and Zinc Oxide Nanoparticles on the Tobacco Cutworm, *Spodoptera litura* (Fabricius)

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Introduction

The tobacco cutworm, *Spodoptera litura* (Fabricius), is a highly destructive polyphagous pest that has developed resistance to many conventional insecticides, necessitating the exploration of novel, environmentally benign control strategies.

Objectives:

This study aimed to evaluate the physio-morphological, enzymatic, and immunological impacts of green-synthesized silver nanoparticles (AgNPs) and zinc oxide nanoparticles (ZnONPs), mediated by *Ficus religiosa* leaf extract, in comparison with the commercial diamide insecticide Coragen®.

Methodology:

Nanoparticles were characterized using UV–visible spectroscopy and X-ray diffraction. Laboratory bioassays assessed dose-dependent toxicity against second instar larvae. Sublethal effects on development, morphology, immune response, biochemical composition, and enzymatic activity were evaluated, including total hemocyte count (THC), protein and lipid content, antioxidant enzymes (catalase and superoxide dismutase), and digestive enzymes (amylase and lipase).

Results:

Coragen® exhibited the highest toxicity with an LC_{50} of 85.05 mg/L, causing 91.67% mortality at 120 mg/L, while AgNPs showed an LC_{50} of 436.27 mg/L. ZnONP exposure significantly prolonged larval duration (18.4 days) and reduced pupal weight (0.226 g) compared to controls (16.8 days; 0.291 g). Severe morphological deformities were observed, with 0.1 ppm AgNPs inducing abnormal cuticle pigmentation in 100% of larvae and 1 ppm causing 76% mortality during molting. ZnONPs significantly elevated THC (54,666.67 vs. 31,666.67 in controls) and induced marked metabolic stress, evidenced by reduced protein and lipid reserves and increased antioxidant and digestive enzyme activities.

Conclusion & Recommendations

Green-synthesized AgNPs and ZnONPs effectively disrupt the physiological, biochemical, and developmental homeostasis of *S. litura*, demonstrating strong potential as eco-friendly alternatives for inclusion in sustainable Integrated Pest Management programs.

Keywords: *Spodoptera litura,* Green-synthesized nanoparticles, Silver and zinc oxide nanoparticles, Insect physiology and enzymatic stress, Sustainable pest management

Olfactory Response and Mortality Dynamics of *Acheta domestica*: Evaluating Fipronil and Bifenthrin with Carbohydrate-Based Attractants

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Introduction

The house cricket, *Acheta domestica*, is a cosmopolitan pest causing economic losses through damage to household materials and stored food products. Conventional control methods often rely on broad-spectrum insecticides, raising concerns regarding environmental safety and non-target effects.

Objectives:

This study investigated the olfactory preferences of *A. domestica* and evaluated the efficacy of selected insecticides combined with carbohydrate-based attractants to develop optimized bait formulations.

Methodology:

Behavioral responses were assessed using a six-armed olfactometer under a Completely Randomized Design. Attractants including sugar solution, vanilla essence, yeast, molasses, and vinegar were tested using wheat flour as a carrier. Mortality bioassays were conducted with fipronil, bifenthrin, imidacloprid, and permethrin over 24–96 hours. Toxicity parameters were estimated using probit analysis.

Results:

Wheat flour combined with sugar solution exhibited the highest attractancy index (100%), significantly exceeding vanilla essence (76%) and wheat bran (13.61%). Among insecticides, fipronil showed the greatest efficacy, achieving 96.67% mortality at 500 ppm after 96 hours, followed by bifenthrin (83.33%), imidacloprid (76.67%), and permethrin (63.33%). Probit analysis revealed a 24-hour LC_{50} of 1005.04 ppm for fipronil, along with rapid lethal time values. The combination of fipronil with sugar-based attractants resulted in 83.33% mortality, confirming a strong synergistic relationship between attractancy and toxicant uptake.

Conclusion & Recommendations

The integration of fipronil with carbohydrate-rich phagostimulants significantly enhances bait efficacy against *A. domestica*. This targeted baiting approach offers an environmentally sustainable and efficient alternative to conventional insecticide spraying for managing house cricket infestations.

Keywords: *Acheta domestica,* Olfactory behavior, Fipronil-based bait, Carbohydrate attractants, Integrated pest control

Biodiversity of Arthropod Fauna in Agroecosystem in Association with Different Abiotic Factors

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Introduction

Arthropod biodiversity plays a crucial role in maintaining ecological balance in agroecosystems by contributing to pollination, pest regulation, and nutrient cycling. Abiotic factors such as temperature and relative humidity strongly influence arthropod abundance, diversity, and seasonal distribution across crops.

Objectives:

This study aimed to assess the biodiversity, abundance, and order-wise distribution of arthropod fauna associated with major agronomic crops and to evaluate the influence of abiotic factors on population dynamics.

Methodology:

Field surveys were conducted at the University of Agriculture Faisalabad (UAF) campus during 2024–2025 on tomato, cauliflower, wheat, maize, radish, and cabbage crops. Arthropods were collected using hand picking, sweeping nets, and aspirators at regular intervals. Population data were analyzed using the Shannon diversity index to estimate species' richness and abundance. Concurrent meteorological data (temperature and relative humidity) were recorded to determine abiotic associations.

Results:

Peak arthropod populations varied among crops and seasons. Tomato and maize showed maximum abundance on 27 March 2025 at 25.5 °C and 42% relative humidity, while cauliflower and cabbage peaks occurred during cooler conditions. Wheat supported the highest arthropod density at elevated temperatures (33.5 °C). Radish exhibited sustained arthropod abundance during October 2024 under moderate temperature and humidity. Order-wise dominance differed among crops, with Hymenoptera prevailing in tomato and radish, Lepidoptera dominating cauliflower, cabbage, and maize, and Hemiptera being most abundant in wheat. Overall abundance followed the order: Maize > Tomato > Wheat > Radish > Cauliflower > Cabbage.

Conclusion & Recommendations

The study demonstrates that arthropod diversity and abundance are crop-specific and strongly influenced by abiotic factors. Understanding these interactions can support sustainable pest management and biodiversity conservation in agroecosystems.

Keywords: Arthropod diversity, Agroecosystem ecology, Abiotic factors, Species richness, Crop entomology

Efficacy of Potassium Silicate and *Metarhizium Anisopliae* against Fall Armyworm

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Introduction

Fall armyworm (*Spodoptera frugiperda*) is a highly destructive, polyphagous pest that attacks many important crops and poses a major threat to food security in Pakistan. The widespread use of chemical insecticides has led to resistance development and negative environmental impacts, including harm to beneficial organisms and soil health. These challenges highlight the urgent need for eco-friendly and sustainable pest management alternatives that can effectively control fall armyworm while minimizing ecological risks.

Objectives

This study evaluated the bioefficacy of potassium silicate (K_2SiO_3) and the entomopathogenic fungus *Metarhizium anisopliae* against different life stages of fall armyworm. The research aimed to compare the effects of chemical and biological treatments on larval survival, growth, and development. Various concentrations of potassium silicate and fungal conidia were applied to fall armyworm larvae, and subsequent mortality, developmental changes, and infection symptoms were assessed to determine their potential for sustainable pest management.

Methodology

Laboratory bioassays were conducted using varying concentrations of potassium silicate (400 and 800 ppm) and *Metarhizium anisopliae* (1×10^6, 1×10^7, and 1×10^8 conidia mL^{-1}). Treated leaves were provided to fall armyworm larvae, which were then monitored for multiple biological parameters. Mortality rates, mycosis, and sporulation were recorded to assess fungal infection. Larval weight, developmental duration, pupal weight and duration, and adult emergence percentage were also measured to evaluate sublethal effects and overall impact on insect development.

Results

Potassium silicate significantly reduced larval feeding and weight gain, though mortality remained relatively low, with maximum mortality of 16.33% at 800 ppm. In contrast, *Metarhizium anisopliae* caused substantial larval mortality, which increased with higher conidial concentrations. The highest mortality (44.00%) was recorded at 1×10^8 conidia mL^{-1}, followed by 36.63% at 1×10^7 and 25.32% at 1×10^6 conidia mL^{-1}. Fungal infection led to visible mycosis and sporulation within 5–7 days post-application, significantly affecting larval and pupal development and reducing overall insect fitness.

Conclusion & Recommendations

Potassium silicate acts as an effective feeding deterrent, while *M. anisopliae* provides significant biological control of fall armyworms. Their combined integration could offer a sustainable alternative within integrated pest management programs.

Keywords: Fall armyworm, Potassium silicate, *Metarhizium anisopliae*, Biological control, Sustainable pest management

Field Evaluation of Turmeric and Moringa Extracts with Zinc Nanoparticles against Species of Wheat Aphid

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Introduction

Wheat productivity in Pakistan is significantly constrained by aphid infestations, particularly *Sitobion avenae*, *Schizaphis graminum*, and *Rhopalosiphum padi*, which cause yield losses through sap feeding and virus transmission. Traditional chemical insecticides often lead to resistance, environmental contamination, and health risks. Therefore, eco-friendly alternatives are urgently needed. Nanotechnology-based approaches, especially plant-derived nanoparticles, are emerging as promising solutions due to their biodegradability, targeted activity, and lower environmental impact. These botanical nano-insecticides can offer sustainable pest control while supporting integrated pest management strategies.

Objectives:

This study assessed the field efficacy of zinc oxide nanoparticles synthesized using turmeric rhizome and moringa leaf extracts for controlling wheat aphids. Nanoparticles were prepared using green synthesis methods and applied in field trials to evaluate their insecticidal effects against major aphid species. Aphid population dynamics were monitored before and after treatment to determine the impact of the botanical nanoparticles on pest suppression and crop protection under natural field conditions.

Methodology:

Zinc nanoparticles were synthesized via the solvent evaporation method and evaluated under field conditions using a Randomized Complete Block Design (RCBD). The study included three treatments: turmeric-based nanoparticles, moringa-based nanoparticles, and a combined formulation of both. Each treatment was applied at three concentrations i.e. 400, 600, and 800 ppm to determine dose-dependent efficacy. Aphid populations were recorded before treatment application and then monitored at 3, 5, and 7 days after spraying. This design allowed assessment of both immediate and sustained effects of the nano-formulations on aphid suppression.

Results:

All nanoparticle treatments significantly reduced aphid populations compared to the untreated control, indicating strong insecticidal activity of the botanical zinc formulations. Among the treatments, turmeric-based nanoparticles showed the highest efficacy, demonstrating rapid and pronounced reduction in aphid numbers. The combined formulation of turmeric and moringa nanoparticles also provided substantial suppression, although slightly less effective than turmeric alone. Aphid reduction improved with increasing nanoparticle concentration and longer exposure periods, highlighting dose-dependent and time-dependent effects. The combined treatment maintained effective control over the entire observation period, suggesting potential synergistic interactions between the two botanical extracts and improved persistence under field conditions.

Conclusion & Recommendations

Botanical zinc nanoparticles, especially those synthesized using turmeric extract, demonstrate strong potential as eco-friendly tools for managing aphid infestations in wheat. Their effectiveness in reducing aphid populations, combined with lower environmental and health risks compared to synthetic insecticides, makes them suitable for sustainable crop protection. These nanoparticles can be integrated into existing integrated pest management (IPM) programs alongside biological control agents, cultural practices, and resistant varieties to provide effective and environmentally responsible aphid suppression.

Keywords: Wheat aphids, Zinc nanoparticles, Turmeric extract, Moringa extract, IPM

Impact Assessment of Salicylic Acid on Population Dynamics of Aphid Species and Associated Natural Enemies in Canola Crop

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Introduction

Aphids are among the most damaging pests of canola, feeding on plant sap and causing direct yield losses through reduced growth, stunted development, and decreased seed quality. Additionally, aphid infestations can disrupt the ecological balance in fields by affecting beneficial arthropods such as predatory insects and pollinators, which play essential roles in pest suppression and crop productivity. Salicylic acid is a plant signaling molecule that induces defense responses, strengthens plant resistance against aphids and enhances natural protection mechanisms.

Objectives:

This study evaluated the effect of foliar-applied salicylic acid on aphid populations, natural enemy abundance, and key yield parameters of canola. Different concentrations of salicylic acid were applied under field conditions to assess their impact on aphid suppression and the attraction of beneficial arthropods. Yield components such as plant height, pods per plant, and grain production were also measured to determine overall crop response.

Methodology:

Five salicylic acid concentrations (0, 50, 100, 150, and 200 mg L^{-1}) were applied in a Randomized Complete Block Design (RCBD) field experiment conducted during the 2024–25 canola season. Treatments were replicated three times, and the crop was monitored throughout the growing period. Weekly observations were made to record aphid populations, as well as the abundance of natural enemies such as spiders, coccinellids, syrphid flies, and mites. Key yield parameters, including plant height, pods per plant, and grains per pod, were also measured. All data were statistically analyzed to determine treatment effects.

Results:

Salicylic acid significantly reduced aphid populations in canola, demonstrating a strong dose-dependent effect. The highest reduction (93.8%) was observed at 200 mg L^{-1}, indicating that higher concentrations effectively suppress aphid infestations. In addition to directly reducing pest numbers, salicylic acid enhanced the attraction of beneficial arthropods, including spiders, coccinellids, syrphid flies, and mites, which contribute to natural pest control. These positive ecological effects were accompanied by improvements in yield parameters, with significant increases in plant height, number of pods per plant, and grains per pod at higher salicylic acid concentrations. This suggests that salicylic acid not only reduces pests but also supports crop growth and productivity.

Conclusion & Recommendations

Salicylic acid effectively suppresses aphid populations by inducing plant defense responses, reducing pest pressure in canola fields. At the same time, it enhances the activity and abundance of beneficial arthropods such as spiders, coccinellids, syrphid flies, and mites, which contribute to natural pest regulation. Improved plant health and reduced pest damage lead to enhanced yield parameters, making salicylic acid a promising and sustainable tool for integrated canola pest management programs.

Keywords: Salicylic acid, Canola, Aphid management, Natural enemies, Induced resistance

Conspecific Density and Diet-Dependent Effects on Development Rate and Survival of *Aedes Aegypti*

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Introduction

Aedes aegypti is the primary vector of dengue, causing widespread illness and placing heavy economic and public health burdens on communities globally. The mosquito population growth and disease transmission potential are closely linked to larval survival and development, which are strongly influenced by the density of larvae in breeding habitats and the availability of nutrient-rich food sources. High larval density increases competition and mortality, while sufficient nutrition accelerates growth and enhances adult fitness.

Objectives:

This study investigated how varying conspecific density and diet quality affect survival, development rate, and body size of *Aedes aegypti* under controlled laboratory conditions. Larvae were reared at different population densities and nutrient levels, and subsequent effects on mortality, developmental timing, and morphometric traits such as body length and wing size were measured.

Methodology:

Larvae were reared under controlled laboratory conditions at different population densities and diet levels to simulate varying resource availability. Each experimental group was monitored from hatching to adult emergence, and detailed observations were made regarding mortality rates, duration of larval and pupal stages, and overall development time. Adult mosquitoes were measured for morphological traits including body length, width, and wing size. The collected data were then statistically analyzed to determine the effects of density and diet on mosquito fitness and growth.

Results:

Larval mortality increased significantly as population density rose, indicating that overcrowding intensifies competition for limited food and space, leading to higher death rates. Conversely, improved diet quality and quantity enhanced larval growth, resulting in faster development and reduced time required to reach pupal and adult stages. Morphometric traits, such as body size and wing length, also showed significant variation depending on both density and diet conditions. These differences were especially pronounced in male mosquitoes, which exhibited greater sensitivity to nutritional changes and crowding. Overall, density and diet strongly influenced mosquito fitness, growth, and developmental success.

Conclusion & Recommendations

Optimizing larval density and diet is essential for successful mass-rearing of *Aedes aegypti*, as it directly impacts survival, development rate, and adult quality. Controlled rearing conditions ensure consistent production of healthy, robust mosquitoes, which is particularly important for sterile insect technique (SIT) programs that require large numbers of competitive males. Proper density and nutrition help maximize yield, reduce mortality, and improve mating performance in released populations.

Keywords: *Aedes aegypti*, Larval density, Diet quality, Development rate, SIT

Impact of Human Blood Groups on Life History of *Aedes Aegypti* (Culicidae: Diptera)

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Introduction

Blood-feeding behavior plays a critical role in determining mosquito survival, reproductive success, and vector competence for disease transmission. The quality and type of blood meal directly influence egg production, longevity, development rate, and overall physiological fitness of mosquitoes. Variations in human blood groups may affect feeding preference, digestion efficiency, and nutrient availability, thereby altering mosquito life-history traits. A clear understanding of mosquito blood group preferences can support the optimization of laboratory mass-rearing techniques and enhance the effectiveness of advanced vector control strategies, including sterile insect techniques, population suppression, and replacement programs aimed at reducing the spread of mosquito-borne diseases.

Objectives:

This study investigated how different human blood groups influence feeding preference, survival rate, and reproductive performance of *Aedes aegypti*. By comparing multiple blood types, the research assessed variations in blood meal acceptance, adult longevity, and egg production to better understand factors affecting mosquito fitness and population development.

Methodology:

Using an artificial blood-feeding system, adult female mosquitoes were offered blood meals from eight different human blood groups under controlled laboratory conditions. After feeding, key biological parameters including oviposition rate, adult survival, larval emergence, and developmental duration were carefully monitored and recorded to evaluate the influence of blood group variation on mosquito life-history traits.

Results:

The results revealed a clear preference of mosquitoes for O^+ and O^- human blood groups, as evidenced by higher feeding rates and significantly greater egg production following blood meals from these groups. Females that fed on O-type blood exhibited enhanced reproductive performance and improved survival compared to those fed on other blood groups. In contrast, AB^+ and AB^- blood groups were least preferred, resulting in reduced feeding success, lower oviposition rates, and comparatively diminished reproductive output. These findings highlight the role of blood group variability in shaping mosquito feeding behavior and reproductive fitness.

Conclusion & Recommendations

Blood group preference can significantly influence mosquito fitness by affecting feeding success, nutrient intake, and reproductive output. These differences may alter vector–host interactions in natural populations and impact disease transmission dynamics. Additionally, understanding blood group preference can improve mass-rearing efficiency for research and control programs by optimizing blood meal selection.

Keywords: *Aedes aegypti, Blood group preference, Oviposition, Vector biology, Mosquito fitness*

Keyword Index (Alphabetical, Unique)

A

Agri-food value chains
Agricultural adaptation
Agricultural economics
Agricultural policy
Agricultural productivity
Agroecological practices
Agroecosystem ecology
Antimicrobial property
Antioxidant property
Arid agriculture
Arthropod diversity

B

Biocement
Biodegradable plastics
Biopesticides
Bioremediation
Blended finance
Bone health
Bacterial cultures
Behavioral economics
Biodiversity

C

Climate change
Climate governance
Climate resilience
Climate risk
Climate shocks
Climate-smart agriculture
CNN–SVM hybrid model
Conflict management
Consumer behavior
Consumer preferences
Credit and liquidity constraints
Crop entomology
Crop yield prediction

D

Dietary diversity
Dynamic panel data

E

Ecological footprint
Economic growth
Energy governance
Environmental sustainability
Essential oils

F

Financial development
Financial vulnerability
Food and nutrition security
Food preservation
Food safety
Food security
Functional food

G

Gender equality
Gendered adaptation
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H

Heat stress
Household consumption behavior

I

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Institutional quality
Irrigation conflicts

L

Livelihood diversification
Livelihood resilience
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M

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ND-GAIN Index
Non-farm employment

O

OPEC

P

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Plant protection products
Probiotic
Productivity

R

Renewable energy

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Risk classification

Risk exposure

Rural development

Rural economy

Rural finance

Rural livelihoods

S

Smallholder farmers

Small-scale fisheries

Social psychology

Soil health restoration

Sustainable development

Sustainable livelihoods framework

Sustainable water use

System GMM

T

Technology adoption

Trade openness

U

Urbanization

W

Water conservation behavior

Water scarcity

Women's empowerment

Themes

Sub-Theme	Explanation
Climate-Smart Investments and Resource Use Efficiency	This theme explores innovative economic strategies for optimizing the use of land, water, and energy resources while ensuring long-term productivity and sustainability. Discussions will focus on policy instruments, investment incentives, and institutional reforms that promote efficient input use, renewable energy adoption, and sustainable intensification of production systems.
Market Dynamics, Trade, and Value Chains under Climate Stress	As climate shocks increasingly disrupt supply chains and trade flows, this theme will examine how global and regional markets respond to climate variability. Topics include price stability, export competitiveness, value chain integration, and market-based risk management, with a focus on how economic policies can cushion the impacts on producers and consumers alike.
Risk, Insurance, and Finance for Resilient Farming	Farmers, particularly smallholders, face growing exposure to climatic and financial risks. This sub-theme will explore innovative insurance mechanisms, microfinance models, and blended finance instruments that can help distribute risk equitably and support investment in adaptation technologies. The discussions will emphasize the importance of inclusive and accessible financial systems that strengthen farmers' adaptive capacity.
Behavioral Economics and Farmer Adaptation	Climate adaptation is ultimately shaped by human behavior and decision-making. This theme focuses on understanding how farmers perceive risks, respond to incentives, and adopt new technologies. By applying behavioral insights, the conference seeks to highlight the design of effective nudges, extension services, and policy instruments that encourage sustainable farming practices at the grassroots level.
Public Policy, Institutions, and Governance	Effective governance and policy coherence are vital for scaling up climate-smart interventions. This sub-theme examines how institutional frameworks, policy incentives, and governance mechanisms can facilitate adaptation and transformation. It will explore cross-sectoral coordination, decentralization, and the role of public–private partnerships in driving systemic change.
Food Security and Livelihoods	Climate change poses profound risks to food availability, access, and utilization, disproportionately affecting vulnerable populations. This theme highlights inclusive growth strategies that promote gender equity, youth engagement, and livelihood diversification. It emphasizes that climate-smart agriculture must contribute to not only productivity but also to social justice and human well-being.
Digital Innovation and Agricultural Data	Emerging technologies such as ICT tools, remote sensing, big data analytics, and precision agriculture offer transformative potential for evidence-based decision-making. This sub-theme will focus on digital platforms and data-driven solutions that enhance productivity, monitor environmental change, and strengthen policy formulation for sustainable agriculture.
Valuing Ecosystem Services and Natural Capital	Integrating environmental and economic objectives is fundamental to long-term sustainability. This theme explores how valuation tools, such as Payments for Ecosystem Services (PES), cost-benefit analysis, and green accounting, can align market incentives with conservation goals. Discussions will focus on natural capital accounting, biodiversity valuation, and the economics of land restoration.

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